Low-Level Radioactive Waste
Minimization Evaluation and Strategy

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Oak Ridge Operations Office and the
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Prepared by
Radian International LLC
1093 Commerce Park Drive, Suite 100
Oak Ridge, Tennessee 37830
Doc. #F951208.3TT51
under contract 78B-99080C to
Lockheed Martin Energy Systems

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ACRONYMS AND INITIALISMS

ALARA	as low as reasonably achievable
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CRU	CERCLA/RCRA Unit
DNFSB	Defense Nuclear Facilities Safety Board
DOE	U.S. Department of Energy
DP	Defense Programs
EM	Environmental Management
EPA	U.S.Environmental Protection Agency
ER	Energy Research
FUSRAP	Formerly Utilized Sites Remedial Action Program
GAC	granular activated carbon
INEL	Idaho National Engineering Laboratory
LANL	Los Alamos National Laboratory
LLMW	low-level mixed waste
LLW	low-level radioactive waste
MLLW	mixed low-level radioactive waste
NRC	Nuclear Regulatory Commission
NTS	Nevada Test Site
ORNL	Oak Ridge National Laboratory
P2	pollution prevention
PC	protective clothing
POC	point of contact
PPE	personal protective equipment
PPOA	Pollution Prevention Opportunity Assessment
RCRA	Resource Conservation and Recovery Act
RMMA	Radioactive Material Management Area
SAR	Safety Analysis Review
SRS	Savannah River Site

EXECUTIVE SUMMARY

On September 8, 1994, the Defense Nuclear Facilities Safety Board (DNFSB) issued Recommendation 94-2, "Conformance with Safety Standards at DOE Low-Level Nuclear Waste Disposal Sites," which concluded that the U.S. Department of Energy's (DOE's) low-level radioactive waste (LLW) program required improvement. Part of this recommendation calls for "studies of enhanced methods that can be used to reduce the volume of waste to be disposed of..." (Conway 1994). In response to Recommendation 94-2, DOE developed and submitted to DNFSB an Implementation Plan that included plans to "...undertake an evaluation of its current LLW minimization efforts [which will] identify efforts that are successful in reducing the amounts of LLW requiring disposal with the purpose of developing a strategy for extending successful practices to other applications" (DOE 1995). A Revised Implementation Plan, dated April 1996, has been provided to the DNFSB and was accepted in August 1996.

The Low-Level Radioactive Waste Minimization Evaluation and Strategy document is intended to support the overall strategy for reducing low-level waste at Department of Energy (DOE) sites as outlined in the 1996 Pollution Prevention Program Plan, issued on May 3, 1996. It is designed to be a reference tool to help DOE sites implement successful waste reduction approaches to achieve the waste reduction goals. While this document is not a stand-alone strategy document, it provides tactical methods for sites to use to meet the overall low-level waste reduction goal, which is the strategic objective. It is the responsibility of DOE sites to implement pollution prevention and to contribute to achieving the Department-wide goal. Specific guidance on meeting this goal is provided in the 1996 Pollution Prevention Program Plan.

Clearly, there are many steps that sites must take to reach the pollution prevention goals. They include:

1. Critically evaluating all new processes/activities to determine waste generation before the process/activity is approved for start-up. The cost of waste management must be clearly understood before waste generation starts.

2. Evaluating all existing operations for potential waste reduction or replacement by new processes. The use of the Pollution Prevention Opportunity Assessment (PPOA) methodology is recommended to find and evaluate waste reduction concepts.

3. Changing contracting and subcontracting mechanisms to fully address waste management responsibilities and assign waste reduction goals.

4. Conducting total life cycle cost analysis of projects, including environmental restoration and

decommissioning projects.

5. Assessing the cost/benefit of waste reduction activities to clearly demonstrate that pollution prevention pays.

In addition, changes to facilities, processes and materials must take into account the overall safety and health basis for current operations. No changes should be implemented without adequate review and input from environmental, safety and health professionals on-site.

As with any waste minimization/pollution prevention activity, the overall objective is to reduce the overall amount and/or toxicity (and therefore risk) of a current waste generation practice. The Environmental Protection Agency hierarchy of pollution prevention actions favors source reduction over recycle, and favors these actions over treatment (including volume reduction) and disposal. Where activities intended for waste minimization/pollution prevention would increase the volume of waste, the toxicity of waste, or the treatment/disposal costs, such actions should not be taken.

This strategy document is not intended to be a complete and comprehensive study of low-level waste generation, treatment methods, or waste minimization options. A comprehensive study that provides "trade-offs" between treatment, recycling and source reduction activities would require a separate effort as part of the Research and Development (R&D) Task in Section XI of the Revised Implementation Plan. Similarly, the concept of "indexing" waste generation to production activities to measure the impact of specific waste minimization activities versus waste generation changes due to reduced production will be included in future R&D tasks for Recommendation 94-2.

This report presents the results of an evaluation conducted to identify common LLW generating activities and identifies successful LLW minimization recommendations that can be implemented to reduce the generation of LLW and meet the Department's LLW reduction goal. This evaluation revealed that LLW minimization potential differed depending on a site's mission and that DOE sites can be viewed as having one of two mission types: "operating" or "environmental restoration."

Site status was identified according to the DOE program under which the sites operate. From annual reports, the most commonly identified lead organizations were Defense Programs (DP), Energy Research (ER), and Environmental Management (EM). For the purposes of this report, "operating" sites were defined as primarily operating as production or laboratory facilities under

DP or ER. "Environmental restoration" sites are defined as performing primarily restoration and site cleanup activities under EM. Savannah River Site (SRS) transitioned from DP to EM landlord responsibility in 1995. During meetings with site officials it was determined that SRS is currently performing more like a restoration site. Due to this finding, SRS has been included in the environmental restoration analyses for this document.

Waste generation and waste minimization data were collected from seven DOE facilities, including both operating facilities and restoration facilities as follows:

- Operating:
  - Idaho National Engineering Laboratory (INEL)
  - Los Alamos National Laboratory (LANL)
  - Oak Ridge National Laboratory (ORNL)

- Restoration:
  - Fernald
  - Hanford
  - Rocky Flats
  - Savannah River Site (SRS)

These sites were selected because they represent both EM and DP sites and are located in a broad range of geographic areas.

The information collected in this study indicated that a total of seven major LLW generating activities offered minimization potential for the two types of facilities. The waste generating activities (and each one's major waste minimization recommendations), in order of their overall waste minimization potential, are:

- Operating sites:
  - Suspect waste[1]—downposting and controlled entry
  - PPE use—segregation and entry restrictions
  - Effluent treatment—procedural changes and carbon regeneration
  - Miscellaneous—segregation for volume reduction

- Restoration sites:
  - Remedial activities—reuse and leave in place
  - Decommissioning—recycle/reuse and free release
  - Site investigation—revise techniques and revise decontamination procedures

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[1]For the purposes of this document, suspect waste is waste that, due to the area in which it originated, is presumed to be radiologically contaminated but has not been proved (or disproved) to be radiologically contaminated.

The primary approaches for LLW minimization for remediation activities may be administrative. These would include personnel training; procedural requirements for waste minimization consideration to take place at specified points in the remedial action decision making, design, and implementation process; transfer of information to make project personnel aware of innovative LLW minimization approaches taken for certain kinds of remedial actions; and inclusion of pollution prevention coordinators or staff throughout the planning process.

Another finding of this evaluation was that, based on Fernald waste generation data, as more sites implement full-scale restoration activities, LLW generation has the potential to increase significantly.

Based on data collected and evaluated, the information derived from the case studies in Table E.1 should be implemented across the DOE complex. These activities when implemented, will support the Department's Pollution Prevention Goals issued on May 3, 1996. Copies of this report will be provided to DOE sites for use in reducing the waste from both routine operations and cleanup/stabilization activities in the future.

Table E.1. Recommended LLW approaches

Generating category	Example waste minimization approach	Site	Reduction	Cost Savings
Suspect waste	Downpost laboratory building	Y-12	441,180 lb/year	$1,000,000/year
	Control entry of packaging into radiological area	Y-12	20,000 lb/year	$94,500/year
PPE use	Survey and segregate clean PPE	FUSRAP	Unknown	Unknown
	Restrict entry of personnel into contaminated areas	LANL	Unknown	Unknown
Effluent treatment	Change of process in over filtered area	ORNL	2,600 gal/year (21,892 lb/year)	$2,600/year
Miscellaneous	Segregate waste for proper management	INEL	2,426 ft^3	$335,140
Remediation	Reuse excavated soil	LANL	6,400 lb	$15,481,740
	Leave pond sludge in place	LANL	2,000 yd^3	$667,500
Decommissioning	Recycle steel from building decommissioning	Fernald	3,458 yd^3 (1,420,000 lb)	Unknown
	Decontaminate and sell equipment	Fernald	240,000 lb	$72,500
Investigation	Use well micropurging method	Fernald	6,000 gal/year (50,520 lb/year)	$52,000/year
	Use reusable decontamination tests	INEL	65,000 ft^3	$2.4 million

FUSRAP = Formerly Utilized Sites Remedial Action Program
INEL = Idaho National Engineering Laboratory
LANL = Los Alamos National Laboratory
LLW = low-level radioactive waste
ORNL = Oak Ridge National Laboratory
PPE = personal protective equipment

1. INTRODUCTION

The U.S. Department of Energy (DOE) generates a significant volume of low-level radioactive waste (LLW) from environmental restoration, decommissioning (formerly known as decontamination and decommissioning), and various ongoing research and defense activities. This waste must be disposed of in facilities specifically engineered for LLW. LLW disposal facilities are expensive and capacities are limited. The costs involved in treating, storing, and handling LLW are not insignificant, particularly those costs associated with construction and licensing/permitting of treatment, storage, and disposal facilities.

In response to the requirements of DOE Orders 5400.1 and 5820.2A, Chapter III, and to reduce the personnel and environmental risks and costs associated with the management of LLW and other wastes, DOE facilities have established waste minimization/pollution prevention (P2) programs. The goal of these programs is to reduce the generation of waste at the source, reuse or recycle waste that is generated, minimize costs and risks of treatment of wastes that cannot be prevented or recycled, and identify innovative disposal options that minimize the impact to the environment while minimizing cost.

Although these P2 programs address LLW, on September 8, 1994, the Defense Nuclear Facilities Safety Board (DNFSB) issued Recommendation 94-2, "Conformance with Safety Standards at DOE Low-Level Nuclear Waste Disposal Sites," which concluded that DOE's LLW P2 program required improvement. Part of this recommendation calls for "studies of enhanced methods that can be used to reduce the volume of waste to be disposed of..." (Conway 1994). In response to Recommendation 94-2, DOE developed and submitted to DNFSB an Implementation Plan that included plans to "...undertake an evaluation of its current LLW minimization efforts [which will] identify efforts that are successful in reducing the amounts of LLW requiring disposal with the purpose of developing a strategy for extending successful practices to other applications" (DOE 1995). This report is a result of that evaluation. To further respond to Recommendation 94-2, a mixed low-level radioactive waste (MLLW) strategy document is currently being prepared to supplement the findings of this report. The MLLW report is expected to be completed by the end of calendar year 1996.

In addition, on May 3, 1996, DOE issued a policy statement establishing DOE's P2 goals. This policy statement established a goal of reducing LLW from routine operations by 50% by the end of December 1999, based on the 1993 baseline amount for the Department.

1.1 OBJECTIVE AND SCOPE

This report presents the results of an evaluation conducted as part of DOE's fulfillment of the commitments made in the Implementation Plan related to LLW reduction. For the purpose of this report, LLW is defined as waste typically contaminated with small amounts of radioactivity dispersed in large amounts of material. LLW is generated in most processes involving radioactive materials in the DOE complex, including decommissioning projects. The goal of this report is to identify common LLW generating activities and develop LLW waste minimization options that have waste minimization applicability for all of the DOE sites. The findings of this evaluation can be used to assist DOE sites in reaching DOE's 50% reduction goal for routine LLW.

Based on the Implementation Plan (April 1996), the strategy of this document is to identify successful waste minimization activities, by the use of case studies, for LLW. Therefore, activities such as those listed below, that would move in a more specific direction, were not included:

- life cycle analyses,
- material balances,
- specific isotope analyses, or
- Curie balances.

However, each site should consider these issues when considering implementation of waste minimization options. Specifically, waste minimization options that generate a higher cost or are more hazardous or more difficult to manage (e.g., MLLW or a higher LLW classification) should not be implemented.

This document is not intended to be a complete and comprehensive study of LLW generation, treatment methods, or waste minimization options. It is not the intent of this document to explore "trade-offs" of activities to show their benefits, such as cost/benefit of source reduction techniques vs simple volume reduction techniques and disposal. A comprehensive study that provides the trade-offs between treatment, recycling, and source reduction activities would require a separate effort as part of the Research and Development Task in Section XI of the Revised Implementation Plan. Similarly, the concept of indexing waste generation rates to production activities to measure the impact of specific waste minimization activities vs waste generation changes due to reduced production will be included in future research and development tasks for DNFSB Recommendation 94-2.

This document also does not include a review of potential health and safety impacts of waste minimization options. However, it is recommended that any waste minimization options that involve process changes should first be reviewed by the Environmental Safety and Health organization at the appropriate site. Any process changes should have a Safety Analysis Review (SAR) and a Safety Authorization Basis performed for the facility before any changes in operational procedures or processes are implemented.

1.2 SUMMARY

This evaluation revealed that LLW minimization potential differed depending on a site's mission and that DOE sites can be viewed as having one of two mission types: "operating" or "environmental restoration." For the purposes of this report, "operating" sites were defined as primarily operating under Defense Programs (DP) or Energy Research (ER), and environmental restoration sites operate primarily under Environmental Management (EM). Savannah River Site (SRS) is an exception. SRS is operating under DP, but during meetings with site officials it was determined that SRS is currently operating like an EM site. Due to this finding, SRS has been included in the environmental restoration analyses for this document.

Waste generation and waste minimization data collected from seven DOE facilities, including both operating facilities and restoration facilities as follows:

- Operating sites:
  - Idaho National Engineering Laboratory (INEL)
  - Los Alamos National Laboratory (LANL)
  - Oak Ridge National Laboratory (ORNL)

- Restoration sites:
  - Fernald
  - Hanford
  - Rocky Flats
  - SRS

Next, waste generation rates and successful waste minimization approaches were identified by the project team by reviewing annual reports for 1991, 1992, 1993, and 1994. Phone calls were made to the sites to help identify processes that generate LLW waste. These generating processes were then evaluated and categorized. Waste generation data from annual reports were reported for routine waste and for cleanup/stabilization waste. While both types of waste are generated by almost all DOE facilities, routine wastes are predominate at operating sites, while cleanup/stabilization wastes are predominate at restoration sites.

A workshop was held on March 5, 1996, and a task team evaluated the LLW generating activities, the LLW minimization approaches that have been implemented, and other LLW minimization activities that are currently under development. The waste minimization activities

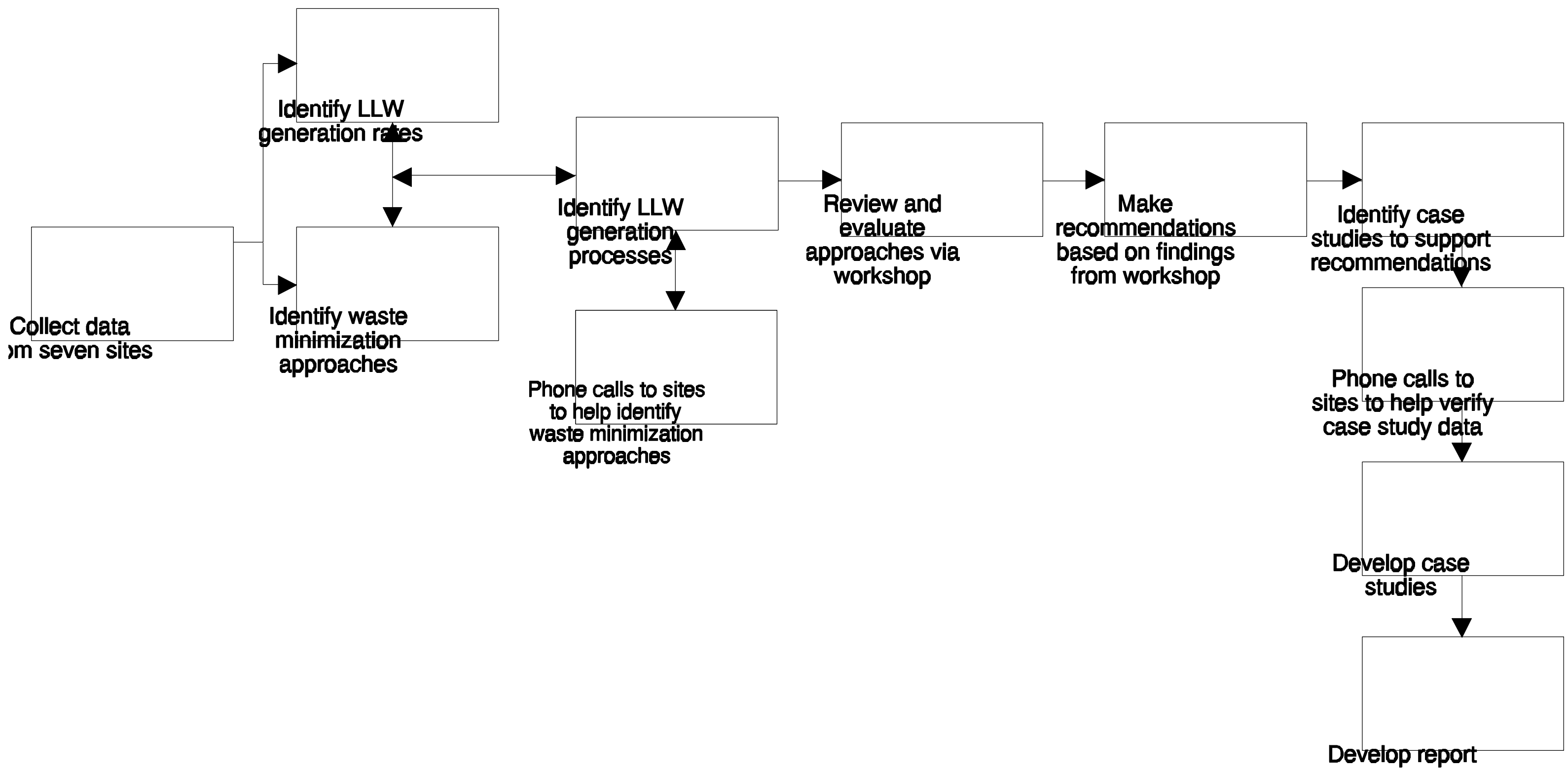

Figure 1.1. Project process flow diagram.

were reviewed and evaluated according to the following criteria:

- economic feasibility,
- quantity of reduction,
- quantity of generation,
- technical risk,
- U.S. Environmental Protection Agency (EPA) hierarchy,
- compliance, and
- application potential.

LLW minimization activities were recommended to be implemented throughout the DOE complex. Finally, case studies that described how some of the approaches have been implemented were developed to support the recommendations.

Figure 1.1 shows how this project was implemented. The project began with the identification of specific approaches, and then the specific approaches were used to identify general approaches in order to assist in making recommendations more applicable to multiple DOE facilities.

1.3 REPORT CONTENT

This report summarizes the findings of this evaluation. Section 2 presents and evaluates the LLW generation data for the seven sites and relates reported waste categories to processes generating the waste, and Section 3 contains process descriptions and evaluates waste minimization data for each generating process. Section 4 presents the proceedings and findings of a LLW task team workshop that was held to evaluate the LLW minimization approaches. Section 5 presents case studies for each of the recommendations developed by the task team. Section 6 presents a summary of Sections 2 through 5. Appendixes A through G contain data that supplement Sections 2 through 5.

2. LLW GENERATION

LLW generation data from the seven sites for 1991, 1992, 1993, 1994, and when available, 1995 were obtained from annual reports and site contacts. This section describes the reporting categories for LLW and relates those reporting categories to processes generating LLW. To the extent possible, generation rates related to each waste category are presented. Note that some sites are generating, or will be generating, large volumes of waste from cleanup/stabilization activities. Other sites will continue to generate waste from routine operations. While information on the volume of future LLW waste generation is presented in the LLW Projections Report (July 1996), it was not available for this report.

2.1 METHODOLOGY

The objective of this evaluation was to analyze available data for LLW generation and identify LLW generating processes at DOE facilities. The seven sites previously identified were chosen for the data collection effort. These sites were chosen so that collected data would represent the spectrum of DOE activities, missions, and field offices. They were also chosen because they represent a variety of geographic locations and geologic conditions, which affect site operations.

Generation data were initially collected from the *Annual Report on Waste Generation and Waste Minimization Progress 1991-1992*, which provides a summary of waste generation for all DOE facilities, and the *1993 and 1994 Annual Reports on Waste Generation and Waste Minimization Progress* for each of the seven sites. The LLW generation data are more detailed by waste category in the latter reports. While the annual reports did not provide specific descriptions of waste generating processes, this information was obtained from site contacts and from interpretation of reported waste minimization approaches.

Site personnel were contacted via telephone and interviewed to confirm the generation data from annual reports and to obtain descriptions of the major waste generating processes, if known. Initial points of contact (POCs) for each facility were identified from annual reports, and additional contacts were interviewed at the referral of the POC. Appendix A contains a list of key contacts at each site.

2.2 DEFINITIONS

The LLW generation data reported in this section were collected from two primary sources, the annual reports and phone interviews with site personnel. The LLW generation rate is based

[redacted]

on the volume of waste received into treatment, storage, and disposal facilities within the given calendar year. This generation rate does not take into account those wastes being held at satellite storage facilities. Therefore, the annual generation rate is not necessarily correlated to process generation rates since LLW is transferred to the storage and disposal facilities in batches.

Each site reports its LLW in six different categories: liquid, solid, inventory, routine, cleanup/stabilization, and process wastewater. These categories are independent of the waste generating process and specific management method for the waste. The latter four terms as used in the annual reports are defined below.

- *Inventory waste* is defined as the total amount of waste in inventory at a site as packaged for treatment, storage, and disposal, including wastes generated in all previous years.

- *Routine waste* is defined as waste produced from any type of production, analytical, and/or research and development laboratory operations; treatment, storage, and disposal operations; “work for others”; or any other periodic and recurring work considered ongoing in nature.

- *Cleanup/stabilization waste* is defined as one-time operations waste, such as wastes produced from restoration activities, including primary and secondary wastes associated with retrieval and remediation operations; "legacy wastes"; and decommissioning/Transition operations.[2]

- *Process wastewater* is any water produced during manufacturing or processing operations that comes into direct contact with or results from the production or use of any new material, intermediate product, finished product, by-product, or waste product. This determination is independent of the level and/or nature of the contaminants.

LLW is also tracked according to management categories, such as compactible, noncompactible, and combustible wastes. These management categories are also assigned independent of the generating process. The generating processes vary from site to site, but ubiquitous sources would include such processes as suspect waste generation and personal protective equipment (PPE) use. In order to better understand the breakdown of LLW into these different categories, the relationships among them are illustrated in Fig. 2.1. In Section 2.3, correlations are drawn between some of the LLW reporting categories and LLW generating processes. Further correlations between the generating process and the types of LLW generated are presented in Section 2.5 and in greater detail in Section 3.

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[2]Remedial activities conducted under a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Record of Decision will have a waste management plan incorporated into the planning process. Wastes that may be generated in addition to PPE and suspect waste include known contaminated soils, sludges, residues, underground tanks, pond liners, and water.

2.3 ANNUAL REPORT LLW GENERATION DATA

The total LLW generation rates are part of annual reports for each of the seven DOE facilities included in this study. Individual reports for each facility were not available for reporting years 1991 and 1992. The LLW generation data for these years were taken from a summary report titled *Annual Report on Waste Generation and Waste Minimization Progress 1991-1992*, and only information with regard to liquid and solid LLW volumes were available for these years. The annual reports for 1993 and 1994 contain more descriptive information with regard to the different categories of LLW, such as LLW inventories, routine LLW, cleanup/stabilization LLW, and process wastewater. This information is summarized by year for each facility in Tables 2.1 through 2.4. These tables identify sites as operating or restoration based on the information in annual reports, which identified them as having a mission of DP (operating site) or EM (restoration site).

Table 2.1. LLW generated at seven DOE sites—CY 1991[a]

	1991 LLW volumes (m^3)					
	Liquid	**Solid**	**Inventory**	**Routine**	**Cleanup/ stabilization**	**Process wastewater**
Operating sites						
INEL	0	896	NR	NR	NR	NR
LANL	0	5,770	NR	NR	NR	NR
ORNL	0	1,940	NR	NR	NR	NR
Rocky Flats	0	1,405	NR	NR	NR	NR
SRS	0	21,632	NR	NR	NR	NR
Restoration sites						
Fernald	0	6,670	NR	NR	NR	NR
Hanford	0	3,874	NR	NR	NR	NR
Total	0	42,187	NR	NR	NR	NR

[a]Data shown in this table represents waste generated by Defense Programs, Environmental Management, Environmental Restoration, and Nuclear Energy.

DOE = U.S. Department of Energy
INEL = Idaho National Engineering Laboratory
LANL = Los Alamos National Laboratory
LLW = low-level radioactive waste
NR = not reported
ORNL = Oak Ridge National Laboratory
SRS = Savannah River Site

Table 2.2. LLW generated at seven DOE sites—CY 1992[a]

	1992 LLW volumes (m^3)					
	Liquid	Solid	Inventory	Routine	Cleanup/ stabilization	Process wastewater
Operating sites						
INEL	0	1,077	NR	NR	NR	NR
LANL	0	2,336	NR	NR	NR	NR
ORNL	0	2,687	NR	NR	NR	NR
SRS	0	12,442	NR	NR	NR	NR
Restoration sites						
Fernald	0	12,571	NR	NR	NR	NR
Hanford	0	2,291	NR	NR	NR	NR
Rocky Flats	0	679	NR	NR	NR	NR
Total	0	34,083	NR	NR	NR	NR

[a]Data shown in this table represents waste generated by Defense Programs, Environmental Management, Environmental Restoration, and Nuclear Energy.

DOE = U.S. Department of Energy
INEL = Idaho National Engineering Laboratory
LANL = Los Alamos National Laboratory
LLW = low-level radioactive waste
NR = not reported
ORNL = Oak Ridge National Laboratory
SRS = Savannah River Site

Table 2.3. LLW generated at seven DOE sites—CY 1993[a]

	1993 LLW volumes (m^3)					
	Liquid	Solid	Inventory	Routine	Cleanup/ stabilization	Process wastewater
Operating sites						
INEL	0	2,583	1,390	1,891	692	139,000
LANL	0	2,693	224,000	2,120	576	21,400
ORNL	0	1,655	676	1,655	0	1,590
SRS	0	14,100	648,000	12,590	1,510	0
Restoration sites						
Fernald	72	4,970	343,000	2,152	2,890	1,910,000
Hanford	0	3,390	590,000	3,120	265	0
Rocky Flats	0	691	4,040	691	0	0
Total	72	30,082	1,811,106	24,219	5,933	2,071,990

[a]Data shown in this table represents waste generated by Defense Programs, Environmental Management, Environmental Restoration, and Nuclear Energy.

DOE = U.S. Department of Energy
INEL = Idaho National Engineering Laboratory
LANL = Los Alamos National Laboratory
LLW = low-level radioactive waste
NR = not reported
ORNL = Oak Ridge National Laboratory
SRS = Savannah River Site

Table 2.4. LLW generated at seven DOE sites—CY 1994[a]

	1994 LLW volumes (m^3)					
	Liquid	**Solid**	**Inventory**	**Routine**	**Cleanup/ stabilization**	**Process wastewater**
Operating sites						
INEL	0	4,278	2,670	1,922	2,356	24,416
LANL	0	2,830	227,000	1,877	946	19,700
ORNL	0	2,490	2,360	1,033	1,457	0
SRS	0	8,250	662,000	6,850	1,400	0
Restoration sites						
Fernald	9	30,600	15,700	583	30,000	3,260,000
Hanford	0	4,120	602,000	3,900	218	0
Rocky Flats	3	537	4,620	458	79	0
Total	12	55,337	1,516,350	17,129	38,180	3,279,700

[a]Data shown in this table represents waste generated by Defense Programs, Environmental Management, Environmental Restoration, and Nuclear Energy.

DOE = U.S. Department of Energy
INEL = Idaho National Engineering Laboratory
LANL = Los Alamos National Laboratory
LLW = low-level radioactive waste
NR = not reported
ORNL = Oak Ridge National Laboratory
SRS = Savannah River Site

In the reports, no distinction is made between a value of zero and not reported for process wastewaters. Therefore, it is uncertain whether the multiple zero entries for process wastewater represent actual zero generation or simply a lack of reporting. However, because the reporting of liquid LLW is required, the zeros in this category should actually represent zero. Therefore, as shown in Tables 2.1 through 2.4, there are only two instances of liquid LLW reported for any of the DOE sites from 1991 to 1994. The reporting of generation data for process wastewater is optional in the annual reports. Large volumes of process wastewater were reported from Fernald in 1993 and 1994 and INEL in 1993. Fernald operations primarily consist of remediation, and all wastewaters generated from these activities are reported as process wastewaters treated prior to discharge.

For comparative purposes, the seven DOE sites were subdivided into two groups. The first group currently consists of ORNL, INEL, and LANL. These sites are referred to as operating sites. These sites have active, multi-program missions such as basic and applied research laboratories as well as scientific and engineering capabilities in support of national energy and defense programs. The operating sites also have active restoration and decommissioning programs,

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Figure 2.2. Solid LLW generation rates for restoration sites.

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Figure 2.3. Solid LLW generation rates for operating sites.

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Fig. 2.5. Routine versus cleanup/stabilization LLW generation 1994.

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Fig. 2.4. Routine versus cleanup/stabilization LLW generation 1993.

but these are not the primary missions at these sites. The second group currently consists of Fernald, Hanford, Rocky Flats, and SRS. These sites are referred to as the restoration sites. A major part of the mission at these sites is remediation, deactivation, and decommissioning. Although SRS was identified as an operating site in the 1994 annual report, it was established at the workshop (described in Section 4) that SRS had transitioned to primarily a restoration mission. Comparisons were made by site from year to year, among sites within a certain group, and between the two groups.

The solid LLW generation rates for the restoration sites are presented in Fig. 2.2. The single largest generator of LLW within a given year was Fernald, while the largest generator on average was SRS. The generation of LLW at Fernald fluctuates over time with a general increasing trend. The reason for this is the large amount of LLW generated from restoration activities currently underway at this site. The trend at SRS seems to be a reduction in LLW generation over the last 4 years. SRS personnel indicate the reason for this decline is primarily due to better packaging of LLW and rollbacks of the radiological buffer areas. The solid LLW generation rates at Hanford and Rocky Flats remain fairly constant from 1991 to 1994, during which time defense operations at each site were shut down. In the late 1980s, Hanford stopped the production of plutonium and switched to a complete restoration mission. In 1992, the Rocky Flats mission changed from nuclear weapons production to restoration, including cleanup, deactivation, and preparation for decommissioning.

The solid LLW generation rates for the operating sites are presented in Fig. 2.3. On average, LANL was the largest generator of LLW over the time period of interest. INEL was the single largest generator of LLW (1994). The generation of LLW at INEL shows a marked increase from 896 m^3 in 1991 to 6510 m^3 in 1994. However, INEL shipped some LLW in 1994 that was actually generated and packaged in prior years. LANL experienced an initial decrease in the generation of LLW followed by an increasing rate over the next 3 years. The generation of LLW at ORNL has fluctuated over the last 4 years. The difference between the generation rate from 1993 to 1994 is due almost entirely to cleanup/stabilization LLW generation.

In the 1993 and 1994 annual reports, solid LLW was further subdivided into routine and cleanup/stabilization waste generation. These amounts are shown for all sites in Figs. 2.4 and 2.5. In most cases, the amount of routine LLW generated annually was greater than that of cleanup/stabilization generated LLW. There is one notable exception, Fernald. In both 1993 and 1994, the cleanup/stabilization LLW generation exceeded the routine LLW generation. This is due to a shift from production of uranium metal (terminated July 1990) to remediation and decommissioning activities. The major processes that contribute to the overall routine and cleanup/stabilization waste categories are discussed in Section 3. If Fernald is an indicator of the

amounts of LLW generation from sites undergoing decommissioning activities, DOE will realize significant increases in LLW generation as more restoration activities are implemented at other sites.

2.4 SITE INTERVIEW LLW GENERATION DATA

In addition to generation data contained in annual reports, telephone interviews were conducted with various site contacts. At Fernald and Rocky Flats, some data were available in regard to the source of the LLW and the types of LLW generated. That information is presented in Table 2.5.

Table 2.5. Site-provided LLW generation data

Sources of LLW generation	Fernald—CY 1995 (percent by weight)	Rocky Flats—CY 1995 (percent by volume)
Suspect waste	<1	
Wastewater treatment	5	
Sample analysis	<1	
Investigation activities	<1	
Decommissioning	5	
Remedial activities	20	1
Waste management	49	
Landlord activities	3	
Not assigned	17	88
National conversion pilot project		11

LLW = low-level radioactive waste

The bulk of the waste management LLW generated in CY 1995 at Fernald is from the overpacking of process residues for shipment to the Nevada Test Site (NTS) for disposal. This is consistent with observations in the decline of inventory waste at Fernald over the last year. Also, as expected for Fernald, the largest source of LLW is from restoration activities. The Fernald waste from the "not assigned" category contains about one-half waste that has not yet been assigned a project code. The LLW at Rocky Flats is not broken into as many generating sources as Fernald. However, the "not assigned" category includes waste from decommissioning, Resource Conservation and Recovery Act (RCRA) closure, residue stabilization, and routine activities.

Based on the available data on LLW generation, it is not possible to identify any overall trend toward reduction. Each site is unique with regard to fluctuations in LLW generation rates from year to year. For example, when a process that historically has produced LLW is shut down, it is sometimes difficult to distinguish the reduction in LLW from this and other P2 programs in effect across the facility. The benefits of P2 programs need to be measured on a project basis and in direct relation to previous generating processes. Conversely, increases in LLW generation rates are usually associated with restoration operations, such as remediation activities or decommissioning, as was discussed for Fernald.

2.5 LLW GENERATING PROCESSES RELATED TO WASTE REPORTING CATEGORIES

The annual reports do not provide data that directly relate waste generating rates to individual processes. Discussions with site representatives indicated the general types of processes that generated LLW at their sites. A description of each of these generating processes is necessarily intertwined with a discussion of the steps taken to minimize LLW generated by these processes. Hence, process descriptions are provided in Section 3 as waste minimization approaches are discussed. As demonstrated in Section 3, the identified LLW minimization approaches can be related back to seven major waste generating activities. These activities and their association with the routine and cleanup/stabilization waste reporting are as follows:

Routine and cleanup/stabilization

- Suspect waste generation
- PPE use

Routine

- Effluent treatment
- Miscellaneous

Cleanup/stabilization

- Remedial activities
- Decommissioning
- Investigative activities

As shown in the following sections, discussions with site personnel revealed that routine wastes are priority for operating sites, while cleanup/stabilization wastes are priority for restoration sites.

3. LLW MINIMIZATION APPROACHES

This section describes the methods and resources used to collect LLW minimization data, annual waste reduction data, the approaches implemented to realize those reductions, and the relationship of the approaches to the processes generating the waste. As presented in Section 2, the priority waste for operating sites (laboratories) is routine waste, while the priority waste for restoration sites is cleanup/stabilization waste. Therefore, waste generating activities and corresponding waste minimization are segregated into those priorities for operating sites and for restoration sites. As presented in Section 4, discussions at the LLW minimization workshop revealed that, although suspect waste and PPE are generated by both routine and cleanup/stabilization activities, they are a higher priority for operating sites. Therefore, they are discussed with the other routine wastes.

3.1 METHODOLOGY

The initial objective of the evaluation was to identify the LLW minimization approaches that have been implemented at DOE facilities and the processes or activities affected by the approach and to evaluate the success and general applicability of the approach. Seven sites were chosen for the data collection effort as discussed in Section 2.1.

General descriptions of the approaches were initially collected from the *Annual Report on Waste Generation and Waste Minimization Progress 1991-1992* and the *1993 and 1994 Annual Reports on Waste Generation and Waste Minimization Progress* for each of the seven sites. These reports provided brief descriptions of the waste minimization approaches implemented. The descriptions include the approach taken, the activity or process affected, the waste stream affected, and the quantity of waste reduction realized. In addition, the 1994 reports provided data on the time, investment, and cost savings associated with implementing the approach. Information for other DOE sites was included when it was appropriate and readily available.

Site POCs were established as described in Section 2.1. These site personnel were contacted via telephone and interviewed to confirm compiled data, to obtain additional approaches that were not contained in the reports reviewed, and to evaluate the success or failure of approaches. Appendix A contains a list of key site personnel.

In addition, potential LLW minimization options were identified through a review of Pollution Prevention Opportunity Assessment (PPOA) reports that have been performed by DOE on both a facility-specific basis and a DOE-wide basis. These PPOA reports study a specific process or activity and identify potential P2 options for that activity. Although specific data on implementation success, reduction, or cost savings are not available, these reports are identified where applicable and the specific options listed in them are identified in Appendix B.

3.2 ROUTINE WASTE

3.2.1 Suspect Waste

3.2.1.1 Suspect waste generation

DOE Order 5400.5 states that any property "shall be considered to be potentially contaminated if it has been used or stored in radiation areas that could contain unconfined radioactive material or that are exposed to beams of particles capable of causing activation." Suspect waste is generated in a radiological area[3]; it is usually not economically feasible to ascertain by radiological monitoring, process knowledge, or sampling and analysis that the material does not contain radiological contamination. Requirements for the release of materials and equipment from radiological areas to other controlled areas are given in 10 Code of Federal Regulations (CFR) 835.1101 (these requirements are shown in Table C.1 in Appendix C).

The release of items or material for unrestricted use is governed by Chapters II and IV of DOE Order 5400.5. Items must be individually subjected to radiological surveys of all surfaces; contamination levels must not exceed limits specified in 5400.5 as shown in Appendix C, Table C.2. Decontamination efforts must be compatible with the "as low as reasonably achievable" (ALARA) process. Items that cannot be surveyed on every surface can be released only if documentation shows that the values in DOE Order 5400.5 are unlikely to be exceeded because of knowledge of the item's use and representative survey measurements made on comparable items.

The criteria for certain specific radioisotopes of radium or thorium given in 40 CFR 192 for soil contamination are the only existing guidance or requirements for bulk or volume contamination of materials. Waste materials that cannot demonstrably meet the requirements of DOE Order 5400.5 or materials that contain bulk contamination must be retained in a controlled area such as a radioactive waste storage or disposal area. The latest draft of 10 CFR 834, intended to replace DOE Order 5400.5, contains no specific numerical limits for surface contamination. Instead, surface contamination limits will be derived on a case-by-case basis based on the ALARA philosophy (Borders 1996).

[3]See Appendix C for definitions of the terms used for areas established to control radiation exposures and contamination.

It has been estimated (Pollard et al. 1994) that up to 50% of the LLW disposed of at LANL is suspect waste. These authors reported that in the last three months of 1993, LANL disposed of 220 m^3 of LLW and 230 m^3 of suspect waste. They also reported generation by Rocky Flats of approximately 31 m^3/year of LLW (primarily paper and glass) that is not involved in any process involving radioactivity.

The U.S. Nuclear Regulatory Commission (NRC) recently withdrew its "below regulatory concern" policy proposal for LLW due to political opposition. "De minimis" proposals have met a similar fate. Currently, the NRC recognizes two groups of waste—liquid scintillation cocktails and laboratory animal carcasses containing no more than 0.05 µCi of ^{3}H or ^{14}C per gram of waste—as being nonradioactive for the purposes of waste disposal (10 CFR 20.2005). DOE issued its "no rad added" policy (*Performance Objective for Certification of Nonradioactive Hazardous Waste*, February 17, 1995) to avoid the generation of mixed waste with only "suspect" levels of radioactivity. This performance objective declares that, if a material is nonradioactive when it is received, the material does *not* produce a radioactive waste if the following conditions apply:

- No measurable increase in radioactivity above background at a statistically defined confidence interval in volume or in bulk due to DOE operations [except for wastes exempted or excluded by EPA, DOE, or NRC regulations] and
- Compliance with the surface contamination requirements of DOE Order 5400.5.

The first requirement can be expressed mathematically in one of three ways:

- Sample concentration + measurement error ≤ minimum detectable activity
- $(\text{Conc} + \text{error})_{\text{out of process}} \leq (\text{Conc} + \text{error})_{\text{into process}}$
- $(\text{Conc} + \text{error})_{\text{waste}} \leq (\text{Conc} + \text{error})_{\text{known uncontaminated comparable material}}$

Furthermore, if the waste is known to originate from an area outside a designated Radioactive Material Management Area (RMMA), the waste can be classified as nonradioactive. DOE's Oak Ridge Y-12 Plant has taken an approach toward establishing, certifying, and maintaining non-RMMA (Procedure Y70-308, October 6, 1994). Wastes originating from these areas are, by definition, not radioactive. Hence, the production of suspect LLW can be reduced by reducing the size and/or throughput of materials in known RMMAs or, if an approach similar to Y-12 is taken, maximizing the size and throughput of non-RMMAs.

3.2.1.2 Suspect waste minimization

Suspect waste generation is common to all DOE facilities, and due to the stringent policies and regulations that govern the management of this waste, it is one of the largest and most diverse waste streams generated. Table 3.1 presents the major types of LLW minimization approaches that have been implemented to reduce suspect waste at the seven sites in this study.

Table 3.1. Waste minimization approaches reported for suspect waste

Approach number[a]	Approach	Number of sites reporting	Total reduction[b]
1.1	Source reduce and downpost contamination areas	3	1,160.54 m^3 +9,277 kg
1.2	Segregate clean from contaminated waste	4	4,034.75 m^3 +44,265 kg
1.3	Prevent waste from entering contaminated area	3	23.85 m^3 +1,910 kg
1.4	Directly reuse suspect materials	2	87.93 m^3 +21,370 kg
1.5	Decontaminate suspect materials	2	546.58 m^3
1.6	Utilize innovative techniques to reduce container usage	1	91.76 m^3
1.7	Modify equipment	2	>1 m^3

[a]Column one contains a unique numerical identifier that links the approach to the detailed list of approaches in Appendix D.
[b]Some sites report reduction in volume, while others report reductions in mass.

Source reduction can be accomplished by reducing the waste generated in a contamination area (e.g., using double-sided printers), preventing materials from entering the contaminated area (e.g., packaging removal prior to entry), or downposting areas from contamination to radiation or clean areas so that materials entering the area will not be considered suspect when they leave the areas. These approaches have proven to be very effective and implementable. Further reduction potential exists in continued decontamination and downposting of contamination areas, increased identification of opportunities to reduce materials and equipment entering contamination areas (e.g., limit tools to only the essentials when entering a contamination area for maintenance and repair or use dedicated tools for the contamination area), and further identification of opportunities to minimize waste generated within the contaminated areas (e.g., send electronic files to another area for printing).

Segregation of suspect waste also offers opportunities for waste reduction. Waste may be segregated into clean and contaminated based on process knowledge, surveying, and sampling. This requires following rigorous procedures to ensure that the waste is not contaminated and to ensure that workers properly segregate the waste into the appropriate containers. However, some of the approaches that have been implemented, such as the Green is Clean Program and the "sealed, unopened containers" policy, have significantly reduced waste generation and management costs. The Green is Clean Program has been implemented at multiple DOE facilities. It is a program in which administrative controls, process knowledge, segregation, training, and surveying are used to segregate office trash in RMMAs so that it may be disposed of as sanitary waste rather than LLW. The name reflects the use of green tinted trash bags to help personnel correctly segregate the office trash from potentially contaminated trash. This program has proven very successful where it has been implemented. An example of the "sealed, unopened container" policy is Procedure Y70-304 established at the Y-12 Plant. Essentially, this policy entails the certification of a sealed, unopened container of material whose useful life has expired. The material is not considered radioactive if it was stored or used in an area where it would not be subject to activation and if the exterior of the container has contamination levels below those given in Table C.2 in Appendix C.

Although suspect waste is generated as part of the activities discussed in the following sections, it is discussed separately due to its prevalence and the unique regulations and policies that govern its management. The LLW minimization approaches discussed here for suspect waste are not discussed in the following sections except where unique approaches have been developed that may help the reader in implementing the approach.

3.2.2 PPE Use

Regulations in 10 CFR 835 ("Occupational Radiation Protection") require the use of protective apparel for controlling the spread of radiological contamination and for protecting workers against contamination. Section 835.404(g) states that "Protective clothing shall be required for entry to areas in which removable contamination exists at levels exceeding those specified in Appendix D to this part." The *DOE Radiological Control Manual* has a similar requirement in its Table 2-2 (DOE 1994). Appendix D to 10 CFR 835 has been modified as shown in Table C.1 to reflect the values for tritium compounds given in Table 2-2 of the *DOE Radiological Control Manual*.

3.2.2.1 PPE waste generation

Protective clothing (PC) is intended to protect personnel against radioactive contamination, not against exposure to penetrating radiation (e.g., gamma rays). Hence, the *DOE Radiological Control Manual* requires the use of PC for any entry into a contamination area, a high contamination area, or an airborne radioactivity area. PC is not required for entry into areas that are posted only as radiation, high radiation, or very high radiation areas (but may be required for these areas by the Radiation Work Permit if contamination is present). The *DOE Radiological Control Manual* defines a full set of PC and a double set of PC as shown in Table 3.2. The *DOE Radiological Control Manual* also gives guidelines for selecting PC as shown in Table 3.3. Respiratory protection may be required in airborne radioactivity areas (PPE is generally considered to consist of PC and any required respiratory protection). Work performed in hoods or gloveboxes may require only labcoats and gloves sealed to labcoat sleeves, depending on the degree of protection offered by the containment of the hood or glovebox.

Table 3.2. Definitions of full and double sets of PC

Full set of PC	Double set of PC
Coveralls	Two pair of coveralls
Cotton glove liners (optional)	Cotton glove liners (optional)
Gloves	Two pairs of gloves
Shoe covers	Two pairs of shoe covers
Rubber overshoes	Rubber overshoes
Hood	Hood

Source: Appendix 3C of *DOE Radiological Control Manual.*

PC = protective clothing

Table 3.3. Guidelines for selecting PC

	Removable contamination levels		
	Low (1 to 10 times the Table C.1 values)	**Moderate** (10 to 100 times the Table C.1 values)	**High** (> 100 times the Table C.1 values)
Routine	Full set of PC	Full set of PC	Full set of PC, double gloves, double shoe covers
Heavy work	Full set of PC, work gloves	Double set of PC, work gloves	Double set of PC, work gloves
Work with pressurized or large volume liquids, closed system breach	Full set of nonpermeable PC	Double set of PC (outer set nonpermeable), rubber boots	Double set of PC and nonpermeable outer clothing, rubber boots

Note: For hands-off tours or inspections in areas with removable contamination at levels 1 to 10 times the values in Table C.1, labcoats, shoe covers, and gloves may be used instead of full PC.

Source: Appendix 3C of *DOE Radiological Control Manual.*

PC = protective clothing

Other requirements in conjunction with the recommended PC may result in the generation of LLW. For example, sleeves of coveralls must be sealed to gloves; legs must be sealed to shoe covers. Normally, tape is used for this purpose. Dosimeters are usually placed in clear plastic bags and taped to the front of the coveralls. Containers (and sometimes container liners) for holding used PC awaiting recycle or disposal are placed at the exit point from the contaminated area. Because all these items are worn or used in an area with loose (removable) surface contamination or airborne radioactivity, they are considered to be contaminated unless they can be shown to have surface radioactivity levels below those in Table C.2.

If a contamination area cannot be decontaminated to levels below those given in Table C.1, an option given in Article 222 of the *DOE Radiological Control Manual* is to convert the area into a fixed contamination area. Such an area has total contamination levels in excess of Table C.1, but the contaminated surface is stabilized so that the removable contamination is less than that specified in Table C.1. A fixed contamination area does not require PC for entry, but does require routine maintenance and monitoring to ensure that the contamination remains fixed.

3.2.2.2 PPE waste minimization

Because PPE use is so prevalent in the daily activities of many DOE facilities, much attention has been given to ways of reducing the amount of contaminated PPE generated and disposed of. The analysis of LLW minimization approaches implemented at the seven sites in this study revealed a number of approaches aimed at PPE waste reduction. Table 3.4 presents these approaches.

PPE can, in many cases, be considered suspect waste. Therefore, the approaches presented in the previous section can apply to PPE. For example, as shown in Table 3.4, PPE waste may be reduced by preventing it from entering the contaminated area. For PPE, this may be accomplished by reducing PPE requirements, scheduling work to minimize the number of times workers enter and leave the contaminated area (thereby reducing the number of PPE changes), using remote controlled equipment in place of personnel in contaminated areas, and using gloveboxes to physically separate workers from contamination. Note that changes to how PPE is used at a work site or how much time personnel spend in a contaminated area should be developed in conjunction with Environmental Safety and Health organizations.

In addition, PC or PPE requirements for entry into an area can be reduced or eliminated by one or more of the following actions:

- enclosing or containing the source of airborne radioactivity,
- decontaminating all surfaces to levels below the values given in Table C.1, or
- fixing surface contamination so that removable contamination is less than the values in Table C.1.

Table 3.4. LLW minimization approaches reported for PPE

Approach number[a]	Approach	Number of sites reporting	Total reduction[b]
2.1	Prevent materials from entering a contaminated area	3	1,160.54 m^3 +9,277 kg
2.2	Launder PPE[c]	1	277.84 m^3
2.3	Segregate launderable from nonlaunderable PPE and clean from contaminated PPE	1	322 m^3 28.5 m^3
2.4	Extend glovebox glove replacement interval	1	496 m^3
2.5	Substitute lower volume PPE articles	1	119 kg
2.6	Reuse clothing that can no longer be laundered as decontamination rags	1	4.2 m^3

[a]Column one contains a unique numerical identifier that links the approach to the detailed list of approaches in Appendix D.
[b]Some sites report reduction in volume, while others report reductions in mass.
[c]Sites could benefit from additional research to identify more launderable articles, such as Velcro™.

LLW = low-level radioactive waste
PPE = personal protective equipment

A second major type of PPE waste minimization is the use of launderable PPE subject to the requirements of Section 461 of the *DOE Radiological Control Manual*. In recent years, most DOE sites have implemented this option to various degrees. However, the data collected in this study show that the potential for expansion of this approach in more innovative ways and for more exclusive use of the implemented approaches is high. More innovative approaches include the use of launderable rather than plastic bags, Velcro™ or elastic bands in place of tape, and more durable materials that can be washed more times and that will not be easily torn during use and handling. The already implemented approaches may be used to a greater advantage by requiring exclusive use of launderable PPE when available and more efficient segregation (through training, monitoring, container marking, and sampling) of launderable vs disposable PPE.

Additional opportunities exist in two other areas: substitution of PPE that generates a lower volume of waste and reuse of launderable PPE as decontamination rags after it can no longer be laundered and used as PPE due to physical damage or residual contamination that exceeds acceptable limits.

Additional information on PPE waste minimization opportunities is provided in the PPOA for PPE and other PPOAs as presented in Table B.1 of Appendix B.

Although PPE is generated as part of the activities discussed in the following sections, it is discussed separately due to its prevalence, the unique regulations and policies that govern the use of PPE, and the number of LLW minimization approaches that apply specifically to PPE. The LLW minimization approaches discussed here for PPE are not discussed in the following sections.

3.2.3 Effluent Treatment

3.2.3.1 Effluent treatment/residuals generation

Chapters II and III of DOE Order 5400.5 specify the annual dose limits and maximum effluent concentrations for discharges from DOE facilities. Radioactivity removed from liquid or airborne effluents must eventually be managed as a solid LLW. PPE waste (discussed above) is also generated by both air and liquid effluent treatment operations.

Air Effluent. Airborne effluent treatment can produce LLW as sorbent media and filters and frames.

Liquid Effluent. Liquid effluent treatment produces solids as sludges from precipitation or coagulation reactions and from ion exchange or sorbent media and residues from evaporators.

3.2.3.2 Effluent treatment waste minimization

As shown in Table 3.5, LLW minimization approaches for these contaminated media include approaches for minimizing the liquid LLW or air to be treated and approaches for optimizing operating conditions or filter and resin use.

Air Effluent. Approaches to minimize LLW related to airborne effluent treatment have included changing a process to maintain safe working conditions and treatment of the air stream (filtering dust from incoming air or removing moisture from the air prior to entering the high-efficiency particulate arrestor filter) to extend the life of effluent filters. PPE waste (discussed above) is also generated by effluent treatment operations.

Liquid Effluent. Approaches to minimize liquid LLW generation include process optimization to minimize liquid LLW discharge (e.g., recirculating decontamination water), preventing stormwater from mixing with the liquid LLW stream by diverting runoff from contaminated areas and sealing liquid LLW lines to prevent storm water infiltration, and minimizing liquid LLW generated from investigatory and remedial activities (methods for which are discussed in later sections).

Table 3.5. LLW minimization approaches reported for air and liquid effluent-related waste

Approach number[a]	Approach	3Number of sites reporting	Total reduction[b]
3.1	Change process and moisture content to extend HEPA filter life	2	110 filter bags 0.42 m^3
3.2	Modify equipment (filters, cooling water systems, or pumps) to reduce liquid LLW generation	4	23,905.9 m^3 30,696,308 kg 2,600 gal
3.3	Change water use procedures to reduce liquid LLW generation	5	846,424 kg 20,591,000 gal 40–50% of LANL
3.4	Redirect storm water away from contaminated areas and liquid LLW collection systems	2	4,540 kg 182,000 kg
3.5	Reuse liquid LLW rather than clean water when appropriate	1	354,000 kg
3.6	Regenerate GAC	1	63,500 kg
3.7	Segregate clean water from liquid LLW piping system	1	

[a]Column one contains a unique numerical identifier that links the approach to the detailed list of approaches in Appendix D.
[b]Some sites report reduction in volume, while others report reductions in mass.

GAC = granular activated carbon
HEPA = high-efficiency particulate arrestor
LANL = Los Alamos National Laboratory
LLW = low-level radioactive waste

Other approaches include the regeneration of ion exchange resins and granular activated carbon (GAC) filters, optimization of liquid LLW treatment conditions to minimize sludge generation from precipitation, and the use of ion exchange in place of precipitation.

Additional LLW minimization options for waste related to effluent treatment compiled from various PPOA reports are listed in Table B.2 of Appendix B.

3.2.4 Miscellaneous Activities

3.2.4.1 Miscellaneous waste generation

These generating activities are generally low volume generators, but unique opportunities for waste minimization may be offered. This waste is not caused by the other six major categories and often involves waste management operations. This waste may be generated by adding packing material to waste containers, using non-ideal containers, or failing to segregate waste to optimize management options.

3.2.4.2 Miscellaneous waste minimization

Table 3.6 presents the LLW minimization approaches identified for other miscellaneous wastes. These approaches include recycling, use of contaminated equipment or tanks for waste disposal, and proper segregation to allow for better waste management.

Table 3.6. LLW minimization approaches reported for miscellaneous waste activities

Approach number[a]	Approach	Number of sites reporting	Total reduction
4.1	Segregate waste to allow more volume reduction through compaction, combustion, or sizing	3	415.49 m^3
4.2	Recycle or reuse contaminated materials or equipment	3	891.13 m^3
4.3	Modify repair procedures and operating conditions to reduce waste	1	0.6 m^3
4.4	Incorporate waste minimization and waste segregation into project planning packages	2	229,000 kg 39.14 m^3

[a]Column one contains a unique numerical identifier that links the approach to the detailed list of approaches in Appendix D.

LLW = low-level radioactive waste

Wastes such as equipment that may not be proven clean due to the level of effort required to survey all interior surfaces may be reused in other activities where the equipment is needed in a contaminated area. Wastes considered to be contaminated that cannot be reused should be segregated into various waste types. Although waste management is not usually considered a waste reduction activity, segregation will allow some waste reduction because waste that is compacted or combusted is significantly reduced in volume (and usually managed at a lower cost) and bulk waste, such as metal and rubble, can be reduced into smaller pieces so that it can be packaged with less void space, thereby requiring fewer containers and less disposal space. These forms of treatment prior to disposal offer the opportunity to reduce the amount of storage and disposal resources required; therefore, it is very beneficial to properly segregate waste into these categories to the extent possible. Several of the waste minimization approaches related to reopening of B-25 boxes marked as "noncompactible" and resegregating the waste into the categories mentioned resulted in large volume and cost reductions. Data collected during this study indicate that segregation practices could be greatly improved through training, monitoring, marking of containers, and developing procedures. It should be noted that this approach was found to be a key element in reducing waste. Incorporating waste minimization into project planning is discussed in more detail in Section 5.3.1.

Table B.3 in Appendix B presents a summary of other LLW minimization options that were found in available PPOA reports.

3.3 CLEANUP/STABILIZATION WASTE

3.3.1 Remedial Activities

3.3.1.1 Remedial waste generation

Remedial activities conducted under a CERCLA Record of Decision will have a waste management plan incorporated into the planning process. Wastes that may be generated in addition to PPE and suspect waste include known contaminated soils, sludges, residues, underground tanks, pond liners, and water.

3.3.1.2 Remedial waste minimization

Because remedial activities are highly varied, including soil removal, soil and waste stabilization, groundwater or surface water collection, and containment, it is difficult to identify generally applicable approaches that can be used to reduce the LLW generated by these activities. The LLW minimization approaches that were identified in this study are presented in Table 3.7. However, it has been found that, generally, in the process of determining and designing the appropriate remediation option for a site, project personnel take waste management and waste minimization into account and often do not report it as it is considered "good operating procedure." Such activities may include minimizing decontamination by minimizing the frequency of removing equipment from a contamination area, leaving contaminated materials in place when possible, and avoiding cross-contamination.

Table 3.7. LLW minimization approaches reported for remedial waste activities

Approach number[a]	Approach	Number of sites reporting	Total reduction
5.1	Modify remediation procedures to reduce waste	2	80.29 m^3
5.2	Reuse contaminated materials	1	1.6 m^3/34 kg
5.3	Prevent spills	1	354 kg
5.4	Leave materials in place	1	16 m^3

[a]Column one contains a unique numerical identifier that links the approach to the detailed list of approaches in Appendix D.

LLW = low-level radioactive waste

Therefore, the primary approaches for LLW minimization for remediation activities may be administrative. These would include personnel training; procedural requirements for waste minimization consideration to take place at specified points in the remedial action decision making, design, and implementation process; transfer of information to make project personnel aware of innovative LLW minimization approaches taken for certain kinds of remedial actions; inclusion of P2 coordinators or staff throughout the planning process; and use of appropriate decision-making tools. A full discussion of these approaches is presented in Section 5.3.1.

3.3.2 Decommissioning Activities

3.3.2.1 Decommissioning waste generation

Decommissioning activities can generate large volumes of PPE and suspect waste. In addition, contaminated building components (e.g., structural steel, concrete, and glass) and residues from surface removal operations and abandoned process equipment can account for large waste volumes.

3.3.2.2 Decommissioning waste minimization

Table 3.8 presents the waste minimization approaches identified in this study for decommissioning waste. As shown, decommissioning activities present a large potential for LLW reduction through reuse/recycling of both clean and contaminated materials. As discussed for remedial activities, the primary approaches for decommissioning waste may be administrative. Table B.4 in Appendix B presents additional LLW minimization options for decommissioning waste that were obtained from various PPOA reports.

Table 3.8. LLW minimization approaches reported for decommissioning waste activities

Approach number[a]	Approach	Number of sites reporting	Total reduction[b]
6.1	Decontaminate and reuse or recycle materials	3	476.4 m^3 90,800 kg
6.2	Directly reuse materials	2	351.87 m^3 46,754 kg
6.3	Directly recycle metals	1	1,906,800 kg
6.4	Revise decontamination methods[c]	1	Unknown

[a]Column one contains a unique numerical identifier that links the approach to the detailed list of approaches in Appendix D.
[b]Some sites report reduction in volume, while others report reductions in mass.
[c]Technology development activities may be needed before an approach can be effectively used by sites.

LLW = low-level radioactive waste

3.3.3 Investigation Activities

3.3.3.1 Investigatory waste generation

Investigations for RCRA or CERCLA activities at DOE sites are frequently conducted in areas where the ground surface or subsurface is radioactively contaminated. Investigation requirements set by EPA for RCRA or CERCLA sites frequently do not adequately address radiological contamination. Requirements for subsurface investigations can generate copious amounts of plastic from equipment lay-down areas, drill cuttings, water from monitoring well purge and development, and liquids from decontamination of equipment. PPE and suspect waste are also generated during investigations.

3.3.3.2 Investigatory waste minimization

As shown in Table 3.9, the approaches that have been reported for the minimization of investigatory waste primarily relate to the size, frequency, or method of sampling. However, a study of the PPOA for Subsurface Geologic Investigation Waste indicates that much more is being done and that additional steps can be taken to reduce waste generated by investigatory activities. These waste minimization activities include steps to reduce the generation and disposal of soil, water from surface and groundwater sampling and well development, disposable sampling equipment, and plastic used for sampling and decontamination. Table B.5 in Appendix B presents the waste reduction options developed in the available PPOA reports. Due to the increasing emphasis at many sites on environmental characterization, monitoring, and remediation and on the number of options presented in the PPOA that are not being consistently used at all DOE facilities, this is an area that should present a high potential for further waste prevention DOE-wide.

Table 3.9. LLW minimization approaches reported for investigation waste activities

Approach number[a]	Approach	Number of sites reporting	Total reduction
7.1	Change sampling and drilling procedures[b]	2	26.6 m^3
7.2	Revise sample size[b]	1	3,090 kg

[a]Column one contains a unique numerical identifier that links the approach to the detailed list of approaches in Appendix D.
[b]Technology development activities may be needed before an approach can be effectively used by sites.

LLW = low-level radioactive waste

4. LLW MINIMIZATION EVALUATIONS AND RECOMMENDATIONS

This section presents an evaluation of the LLW minimization approaches presented in Section 3 and the recommendations developed from that evaluation. This evaluation was accomplished through a one-day workshop involving participants representing various sites, missions, and geographic locations.

4.1 METHODOLOGY

The primary goals of the task team at the workshop were to:

- evaluate and rank LLW generating categories according to their waste minimization potential and
- evaluate which options within each category have the greatest potential for LLW minimization.

The results of these evaluations were used to develop LLW minimization recommendations that can be implemented throughout the DOE complex to the fullest extent possible. The evaluation was performed by a team of DOE and site contractor personnel. Information from earlier data collection was provided to all members of the task team for review. The team then convened at a one-day workshop where the LLW generating categories and corresponding approaches were discussed. The team also discussed criteria by which to evaluate the approaches and ranked the approaches for each generating category. The information provided prior to the workshop and materials used at the workshop are presented in Appendix F.

4.2 WORKSHOP PROCEEDINGS

4.2.1 Evaluation Criteria and Introduction to Generation Categories

Evaluation criteria used for prioritizing both waste generating categories and waste minimization approaches included the following:

- economic feasibility,
- quantity of reduction,
- quantity of generation,
- technical risk,
- EPA hierarchy,
- compliance, and
- application potential.

Table 4.1 Summary of LLW generating categories and corresponding LLW minimization options

Suspect waste	PPE use	Effluent treatment	Miscellaneous waste	Remedial activities	Decommissioning activities	Investigation activities
Downpost contamination areas	Reduce entry requirements	Extend HEPA filter life	Segregate	Modify remediation procedures	Decontaminate and reuse/recycle	Revise soil sampling and boring procedures
Segregate	Launder/recycle	Modify equipment	Recycle/reuse	Reuse materials	Direct reuse	Revise well sampling procedures
Divert	Segregate	Change procedures	Modify repair procedures	Prevent spills	Direct recycle	Revise well development and purging procedures
Reuse	Substitute	Divert storm water	Proper planning	Leave material in place	Revise decontamination procedures	Revise equipment decontamination procedures
Decontaminate	Reuse in other ways	Reuse liquid LLW				
Reduce container usage		Regenerate GAC				
		Segregate piping				

GAC = granular activated carbon
HEPA = high-efficiency particulate arrestor
LLW = low-level radioactive waste
PPE = personal protective equipment

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Table 4.2 Workshop results for suspect waste

Approach	Economics	Reduction	Generation rate	Technical risk	EPA hierarchy	Compliance	Potential	Total score	Comments
Downposting	2[a]	3	3[b]	3	3	3	3	**20**	
Segregation	2[c]	2	2	2	2[d]	3	3	**16**	
Controlled entry	3[e]	3	2	3	3	3	3	**20**	
Reuse	2[f]	1	1[g]	2	2	2	3	**13**	Example: Use of contaminated containers
Decontaminate	1[h]	2[i]	1[g]	1[j]	1	2[k]	2	**10**	Example: Lead bricks at Argonne—decontaminated entire load
Packaging	3	3	2	3	1	3	3	**18**	Example: Maximize volume in given container
Modify equipment	3	3	2	2	3[l]	1	3[l]	**17**	

[a]May require large effort but possibly large return.
[b]Already implemented at some sites with high volume reduction realized.
[c]High labor cost for segregation.
[d]Segregation is after waste is generated.
[e]Low cost.
[f]Low yield.
[g]Low impact.
[h]Low benefit.
[i]Generates a secondary waste.
[j]High risk of failure.
[k]No regulations for bulk contamination.
[l]Would eliminate this waste category.

EPA = U.S. Environmental Protection Agency

4-4

Table 4.3 Workshop results for PPE waste

Approach	Economics	Reduction	Generation rate	Technical risk	EPA hierarchy	Compliance	Potential	Total score	Comments
Entry restrictions	2.75	2	1.66[a]	3[b]	3	3	3	**18.33**	Remove worker break times to eliminate additional PPE changeouts
Launder PPE	2.66[c]	2[d]	2	3[e]	2	3	3[f]	**17.66**	Safety is number one concern. Could benefit from additional research
Segregation	3[g]	3[h]	2	3[i]	3[j]	3	3	**20**	
Glovebox	1[k]	1	1	3	3	3	1[l]	**13**	
Substitute	2	1.33[m]	1	2[n]	3	3	3	**15.33**	
Reuse	2[o]	1.66	1.66	2	2	3	3	**15.33**	

[a]Audit at SRS indicated increase in volume at SRS.
[b]Proven and demonstrated at many sites.
[c]Economics good for coveralls and booties, but not for gloves and boots.
[d]Increases wastewater, but the water can be treated.
[e]Have to monitor PPE once laundered.
[f]Rules will be set up around monitoring.
[g]No additional time involved for people to segregate clothing.
[h]Materials such as tags, pens, etc., can be set aside at controlled entry points to use again.
[i]Only problem could come in times of human error when materials are improperly segregated.
[j]Reuse/recycle.
[k]High cost only justified for very special applications (95% of time).
[l]Special applications.
[m]Small amount of material affected.
[n]Skeptical because team has not yet seen it implemented.
[o]High cost for shredding launderable PPE.

EPA = U.S. Environmental Protection Agency
PPE = personal protective equipment
SRS = Savannah River Site

Table 4.4 Workshop results for effluent treatment waste

Approach	Economics	Reduction	Generation rate	Technical risk	EPA hierarchy	Compliance	Potential	Total score	Comments
HEPA air filter	2	2[a]	1	2.66	3	3	2	**15.66**	
Equipment modification	2.5[b]	2.66	2	2	2.5[c]	2	3	**16.66**	SRS pump and treat systems getting water below NPDES permit limits (i.e., free release). Potential for future exploration
Change procedures	3	3	2	3	3	2	3	**19**	
Redirect runoff	2.5	2	2	2	3	2	2.33[d]	**15.83**	
Reuse liquid LLW	1	1	1	1.66	2	2	1	**9.66**	Doesn't seem to fit in category. Not good idea to use liquid LLW again
Regenerate carbon	3	2.33	2	3	2	3	3	**18.33**	Look at solid LLW of carbon, not liquid LLW
Segregate/ bypass clean water	2.33	2	2	2.5[e]	3	3	2.66	**17**	

[a]Nothing to compare it to.
[b]Cultural disconnect with business practices.
[c]Not applicable because some are treatment and some are source reduction.
[d]More applicable at sites that have high annual precipitation.
[e]Potential problems because some systems are not designed to be segregated.

EPA = U.S. Environmental Protection Agency
HEPA = high-efficiency particulate arrestor
LLW = low-level radioactive waste
NPDES = National Pollutant Discharge Elimination System
SRS = Savannah River Site

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Table 4.5 Workshop results for miscellaneous waste activities

Approach	Economics	Reduction	Generation rate	Technical risk	EPA hierarchy	Compliance	Potential	Total score
Waste segregation	2[a]	2	1[b]	2	1[c]	3	3	**14**
Recycle/reuse	2[a]	2	1[b]	2	2	2[d]	3	**14**
Change procedures	3	3[e]	1[b]	2	3[f]	2[g]	3	**17**
Project planning	3[f]	3	1[b]	3	3[f]	2	3	**18**

[a]Labor intensive.
[b]Small volumes by definition.
[c]Treatment.
[d]Will have to meet DOT regulations and recycling facility waste acceptance criteria.
[e]Potential may have already been maximized.
[f]Waste will not be generated.
[g]May require EPA approval.

DOT = U.S. Department of Transportation
EPA = U.S. Environmental Protection Agency

4-7

Table 4.6 Workshop results for remedial activities

Approach	Economics	Reduction	Technical risk	EPA hierarchy	Potential	Total score	Comments
Modify remediation	3	3	3	3	3	**15**	Includes "no further action" alternatives
Reuse materials	2[a]	3	3[b]	2	3	**13**	
Prevent spills	1	1	2	3	1[c]	**8**	
Leave in place	2	2	2	2[d]	2[e]	**10**	
Contract language	3	2	3	3	3	**14**	Part of planning
(LCC) Long-term economics	3	2	3	2	3	**13**	Part of planning

[a]Soil washing high cost by direct reuse low; therefore, cost averages moderate.
[b]Soil washing is not always successful.
[c]Have Spill Prevention, Control, and Countermeasures Plans already in place.
[d]Not applicable; no waste generated.
[e]Has previously been implemented.

EPA = U.S. Environmental Protection Agency
LCC = life cycle cost

Table 4.7 Workshop results for decommissioning waste activities

Approach	Economics	Reduction	Technical risk	EPA hierarchy	Potential	Total score
(Free Release) Decon/reuse/recycle	2[a]	2[b]	3	2	3[c]	**12**
Reuse equipment	3	1[d]	1	2	2[e]	**9**
Recycle	3	3[f]	3[g]	2	3[h]	**15**
Revise decon methods	2	2[i]	2[j]	2	2[k]	**10**
Contract language	3	3	3	3	3	**15**
Long-term economics	3	3	3	3	3	**15**

[a]A lot to survey and decontamination required. May be done on-site or off-site (if material has intrinsic value).
[b]Due to shape and configuration, cannot be free released.
[c]Can be done at any DOE site.
[d]On-site.
[e]Cannot release equipment to public.
[f]Can melt nearly all metal regardless of contamination.
[g]Low risk for metal recycling.
[h]High potential for implementation at all DOE sites.
[i]This option affects a smaller secondary waste stream.
[j]Technology development activities may be needed before an approach can be effectively used by sites.
[k]High potential but already being done to a large extent.

DOE = U.S. Department of Energy
EPA = U.S. Environmental Protection Agency

Table 4.8 Workshop results for investigation waste activities

Approach	Economics	Reduction	Technical risk	EPA hierarchy	Potential	Total score	Comments
Planning	3	3	3	3	3	**15**	
Develop/review sampling procedure	1	1	1	3	1	**7**	Technology development activities may be needed before an approach can be effectively used by sites
Revise techniques	2	3	2	3	3	**14**	Technology development activities may be needed before an approach can be effectively used by sites
Revise decontamination methods	3	3	2	3	3	**14**	
Reduce sampling requirements	Decided to include in SAPs/planning						Field screening, regulator negotiations, nonintrusive sampling

EPA = U.S. Environmental Protection Agency
SAP = Sampling and Analysis Plan

4-10

These criteria were to address technical, economic, and environmental issues, as recommended in the Facility Pollution Prevention Guide (EPA 1992). In addition, these criteria were expected to address most DOE site concerns, with the exception of health and safety. Health and safety were not included because it was assumed that sites have ample health and safety guidance and will follow this guidance in implementing (or considering implementation of) any waste minimization activity.

Each generating category received a score of 1, 2, or 3, with 1 representing the least desirable option for that criterion and 3 representing the most desirable option for that criterion. The scores were then summed for each category to establish an overall ranking for the generating categories. LLW generating categories and their corresponding potential waste minimization approaches are summarized in Table 4.1.

4.2.2 Evaluation and Ranking of Generation Categories

The group began to evaluate LLW generation categories to rank them in order of importance. However, upon trying to score each category according to economic feasibility, it was found that differences between operating sites and restoration sites and a lack of full understanding of each category presented barriers to the evaluation. Therefore, it was decided to proceed with breakout sessions to allow each group to become more familiar with the evaluation process, the generating categories, and the related issues. Following the breakout sessions, the ranking of generating categories was revisited as described below.

4.2.3 Breakout Sessions

Waste generating categories were assigned to three working groups in breakout sessions. The groups evaluated and ranked the potential waste minimization options associated with their respective waste generating categories. The participants of each group presented their results to the entire group for discussion. The results of the breakout session discussions are shown in Tables 4.2 through 4.8.

A major finding of these discussions was that the incorporation of waste minimization in the planning stages of any activity was a prerequisite to any other waste minimization approach and applied to all LLW generating activities. Therefore, this option, which includes performance of life cycle cost analyses, incorporation of waste minimization in contracts and requests for proposals, inclusion of P2 representatives in project teams, development of material handling and segregation plans, inclusion of P2 in waste acceptance criteria, and negotiations with regulators, would precede any other option and would apply to all LLW generating categories. Otherwise, the two options with the highest scores were selected.

4-11

4.2.4 Ranking Waste Generating Categories

The group then revisited the ranking of LLW generating categories. The group agreed that it was more appropriate to rank the categories on an overall basis rather than scoring them according to each evaluation criterion. It was quickly agreed that "miscellaneous activities" was the least important generating category. However, ranking of the remaining six categories led to further discussion concerning the difference between operating and restoration facilities. It was then recognized that, due to the differences in waste generation at the two site types, the priority would vary. Therefore, the priority generating categories were identified for each type of site as follows (in order of importance):

- Operating site—suspect, PPE use, effluent treatment, and miscellaneous and
- Restoration site—remediation activities, decommissioning, and investigation.

4.2.5 Documentation of Recommendations

Prior to adjourning, the group reviewed the activities of the day to confirm and document findings and clarify follow-up actions. Findings were documented as follows.

4-12

1. Incorporation of P2 into planning activities is the preferred P2 approach for all types of sites and generating categories, but especially for restoration activities. Approaches that can be used to accomplish this incorporation include:

   - inclusion of P2 personnel on project teams;
   - use of appropriate decision-making tools;
   - incorporation of P2 requirements in contracts and requests for proposals;
   - contractor and employee incentives, such as awards;
   - regulator negotiations to encourage P2; and
   - project team P2 training.

2. For miscellaneous waste generation, changing procedures received the highest score. However, reevaluation by the entire task team led to the conclusion that segregation was applicable to multiple sites and would significantly save disposal site volume and result in cost avoidance. Therefore, it was the preferred waste minimization option for this generating category.

3. Recommendations for the seven generating categories would be prioritized for routine waste (for operating sites) and cleanup/stabilization waste (for restoration sites), as shown below. The group then identified potential sources for case studies that could be used to support each recommendation.

4-13

Type of facility	Generating category (in order of importance)	P2 recommendation
Operating	Suspect waste	Downposting Controlled entry
	PPE use	Segregation Entry restrictions
	Effluent treatment	Change procedures Regenerate carbon
	Miscellaneous	Waste segregation
Restoration	Remediation	Reuse materials Leave in place
	Decommissioning	Recycle/reuse Free release
	Investigation	Revise techniques Revise decontamination methods

P2 = pollution prevention
PPE = personal protective equipment

4-14

5. RECOMMENDATIONS AND CASE STUDIES

This section presents case studies that were developed to illustrate the implementation of the LLW minimization recommendations presented in Section 4.

5.1 OBJECTIVE AND METHODOLOGY

Based on the waste minimization approaches identified in Section 3, and the experience of the team members at the workshop on March 5, 1996, potential case studies were identified. Case studies were compiled based on detailed information supplied by site contractor personnel. The primary contact for each case study is noted in Appendix G.

The objective of this activity was to develop case studies that verify the implementability and applicability of the LLW minimization recommendations developed in Section 4 and provide some insight on implementation issues to assist other DOE sites in identifying where and how to implement the recommendations.

Although it has been established that routine and cleanup/stabilization wastes are prioritized for operating sites and restoration sites, respectively, all seven sites generate both types of waste. Therefore, some case studies for cleanup/stabilization waste were obtained from operating sites, while some case studies for routine waste were obtained from restoration sites. The applicable case studies for chosen recommendations are described below.

5.2 ROUTINE WASTE CASE STUDIES

The major LLW generating categories of routine waste were identified as priorities for operating sites. They include, in order of priority, suspect waste generation, PPE use, effluent treatment, and miscellaneous (specifically, waste management). The case studies for these generating categories and corresponding recommended waste minimization approaches are described below. Note that planning for P2 in routine activities is important. Planning activities are discussed in Section 5.3.1.

5.2.1 Suspect Waste

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The recommendations identified for suspect waste generation were downposting and controlled entry. The case studies for these recommendations are presented below.

5.2.1.1 Downposting

At Y-12, a project was implemented to eliminate LLW generated from a laboratory building.

Contact. Sheila Poligone; (423) 241-2568 (see Appendix G).

Baseline. Building 9995 had approximately 19,000 ft^2 of radiological areas. All materials entering these areas were disposed of as LLW. The layout of the building was such that several nonradiological areas were surrounded by radiological areas, requiring people and materials to pass through radiological areas to get to the nonradiological areas.

LLW Minimization Approach. By consolidating radiological activities to a limited area and restructuring laboratory activities, the size of the radiological area in Building 9995 was reduced to approximately 2300 ft^2. Sample load and activities within the laboratory were not decreased. Rather, operations were made more efficient to produce less waste, and the number of personnel having to perform work in the radiological areas was reduced.

To achieve reductions, the laboratory consolidated radiological sample preparation areas and re-distributed work to separate nonradiological prep areas from radiological prep areas. Additionally, some physical changes were made to reduce the interface boundaries between the radiological and nonradiological areas and to enhance the flow of materials and samples as much as possible. Procedures were modified to identify how radiological operations should be conducted to ensure the protection of the public, employees, and the environment and to control the spread of contamination.

Results. This LLW minimization activity reduced the amount of LLW, primarily PPE, by 441,180 lb/year. Annual cost savings from reduced purchasing, laundering, and disposal costs total over $1 million. The cost to implement this approach included purchase and installation of racks for frisking equipment and radiological area posting materials and labor for decommissioning, health physics oversight, and procedure development and totalled $79,535.

5.2.1.2 Controlled entry

This project involves the elimination of LLW generated from packaging. Information collected from Y-12 and Fernald indicates that this option has a high potential for implementation at most DOE facilities. The case study presented in detail below is the project implemented at Y-12. However, a summary of the Fernald project is also presented to provide further insight.

Contact. Sheila Poligone; (423) 241-2568 (see Appendix G).

Baseline. One Y-12 organization generates approximately 10 tons of LLW packaging per year from unpacking materials in a radiation area.

LLW Minimization Approach. Extend a dock at Building 9212 where materials can be unpacked in a noncontamination area, recycle the packaging material, and take the necessary material into Building 9212. The dock extension is currently in the final design phase and has not yet been constructed.

Results. This LLW minimization activity would eliminate the amount of LLW packaging, thereby reducing the amount of LLW by 20,000 lb/year. The annual cost savings from reduced container and disposal cost was estimated to be approximately $94,500. No significant labor requirement changes are expected. The cost to implement this approach would be the cost to install the extended dock, which is estimated at $210,000.

Similar Projects. A similar project was implemented at Fernald in which a receiving incoming materials inspection area was constructed for unpackaging incoming materials in a clean area to prevent the packaging from entering the radiation area and requiring disposal as LLW. This project has resulted in a LLW packaging reduction of over 3300 ft^3 and a cost savings of approximately $21,000. The implementation cost for purchasing reusable plastic containers for the unpackaged materials was $65,000 and the implementation time was 4 to 5 months.

5.2.2 PPE Use

The recommendations identified for PPE use were segregation and entry restrictions. The case studies for these recommendations are presented below.

5.2.2.1 Segregation

At a Formerly Utilized Sites Remedial Action Program (FUSRAP) site, a project was implemented to reduce LLW generated from the use of PPE in a contaminated area.

Contact. Jason Darby; (423) 241-6343 (see Appendix G).

Baseline. At Schnoor, a FUSRAP site, disposable PC was used in control areas.

LLW Minimization Approach. Materials used in control areas, including disposable clothing (coveralls, gloves, etc.) were surveyed and released as radiologically clean rather than being disposed of as LLW if no contamination was detected. If large portions of the PPE were contaminated, the clothing was disposed of as LLW. If only small areas were contaminated, those areas were cut out and disposed of to minimize the generation of LLW.

Results. No quantitative data are currently available on waste reduction or cost savings for this activity. However, the primary cost avoidance was disposal cost, while the primary added cost was for labor to frisk and segregate the clothing.

5.2.2.2 Entry restrictions

This project involves the elimination of LLW generated from PPE use in remediation activities. Although this case study is similar to suspect waste reduction by downposting, other examples could include the use of gloveboxes or remote equipment. However, no information was available for those examples.

Contact. Jocelyn Siegel; (505) 845-4623 (see Appendix G).

Baseline. A remediation site containing MLLW covered 3 acres. The entire area would normally be classified as an exclusion zone and PPE would have been used throughout.

LLW Minimization Approach. Before starting the remediation effort, a sampling grid 25 by 25 ft was established, preliminary site survey information was used, and field screening methods were used to specify the areas of concern, including contamination reduction zones and exclusion zones. This allowed only specific and limited areas to be designated and marked for exclusion zones that required the use of PPE, reducing the need for PPE and decontamination.

Results. This LLW minimization activity was estimated to have reduced the amount of LLW (or potential MLLW) PPE to approximately 10% of that generated in previous similar activities. Cost savings have not been quantified for this activity.

5.2.3 Effluent Treatment

The recommendations identified for effluent treatment were to change treatment procedures and regenerate GAC. The case studies for these recommendations are presented below.

5.2.3.1 Change procedures

Although changing certain effluent generation and effluent treatment procedures appears to be an approach with high reduction potential, a review of reported approaches that have been taken at the seven sites in this study revealed that most of the approaches were site-specific and do not, individually, present a high potential for generalization and use at multiple sites. However, due to the high potential for the recommendation in general, a case study is presented below to provide an example for other sites. This project involved the reduction of liquid LLW by eliminating a backwash procedure.

Contact. Susan Michaud; (423) 576-1562 (see Appendix G).

Baseline. The currently used prefilters at the High Flux Isotope Reactor cleanup and cooling systems require backwashing with acid and caustic solutions, which generates liquid LLW.

LLW Minimization Approach. As part of a regulatory driven effort to upgrade the High Flux Isotope Reactor, it is necessary to upgrade the prefilters. The new units will not require backwashing and will, therefore, not generate the associated liquid LLW.

Results. This LLW minimization activity will reduce the amount of liquid LLW by 2600 gal. The annual cost savings from reduced treatment cost was estimated to be $2600. The cost to implement this approach (purchasing and installing the new prefilters) is $100,000.

5.2.3.2 Regenerate GAC

A project was implemented at Rocky Flats that reduced the amount LLW generated by the use of GAC units.

Contact. Susan Anderson; (303) 966-3054 (see Appendix G).

Baseline. At Rocky Flats, surface water treatment includes the use of GAC units prior to the water being discharged from the site. Due to the potential for radioactive contaminants to accumulate on the GAC units, the units had previously been handled as LLW. Handling of the GAC units as radioactive waste involved packaging the units as radioactive waste for shipment to a LLW disposal facility and storing the waste until an off-site disposal facility could be identified.

LLW Minimization Approach. Rocky Flats' Surface Water Division negotiated with DOE, the vendor selected to recycle/regenerate the units, and the vendor's home state in order to obtain permission to ship the units off-site for regeneration. Samples of the units were analyzed for contaminants and the results were within acceptable levels for the vendor. It was determined that, provided the units were being recycled/regenerated and not disposed of, they could be sent to the vendor. Potential radioactive contaminants included ^{235}U, ^{238}U, ^{239}Pu, and ^{241}Am.

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Results. This LLW minimization activity reduced the amount of LLW by 140,000 lb. The frequency of this activity is unknown since the need for GAC regeneration is irregular. The cost savings from reduced disposal cost was approximately $700,000 (this is the savings calculated by comparing the total cost for disposal to the total cost to monitor, transport, and regenerate). The implementation cost was considered in calculating the cost savings.

5.2.4 Miscellaneous

The recommendation identified for the miscellaneous category that had potential for being implemented at multiple sites to reduce LLW disposal was waste segregation. Although this option does not reduce at the source, it does reduce the volume of waste being disposed of, thereby preserving disposal space for the future and providing for more efficient container use. The case study for this recommendation is presented below.

5.2.4.1 Waste segregation

At INEL and ORNL, projects were implemented to reduce LLW disposal by segregation of wastes into appropriate management categories to allow for significant volume reduction.

Contact. Tom Wheeler; (208) 533-4137 (see Appendix G).

Baseline. At INEL and ORNL, waste is packaged by many personnel as the need exists. Waste containers labeled as noncompactible are sent straight to disposal, without further treatment or regard for volume reduction. Other management activities, including compaction, incineration, and free release, require additional handling and special attention to the careful segregation of waste. Therefore, in the past it was more cost-effective, for the generator, to dispose of most waste as noncompactible.

LLW Minimization Approach. Studies have been conducted at INEL and ORNL in which legacy waste packages were reopened, inspected, segregated, and repackaged. At the INEL Test Reactor Area, 6048 ft^3 of suspect noncompactible waste was repacked from wooden boxes and a B-25 bin. At ORNL, a study of B-25 boxes is currently underway. The results of the repackaging are presented in Table 5.1.

Both of these studies indicate that significant volume reductions (40 to 69%) can be achieved in suspect waste generation through inspection and repackaging of inventory waste and instituting tighter management control over initial packaging of LLW.

Table 5.1. Repackaging of suspect waste at INEL and ORNL

Waste type	INEL	ORNL
Free release	40%	69%
Compactible	9	3%
Combustible	5	20%
Noncombustible	11	8%
Asbestos (noncompactible)	4	
Metal and wood sizing	31	

INEL = Idaho National Engineering Laboratory ORNL = Oak Ridge National Laboratory

Results. At INEL, this LLW minimization activity reduced the volume of LLW to be disposed of to 3622 ft^3, less than 60% of the original volume. Labor to manage the waste was $20,460 for repackaging but decreased by $1800 for shipping, for a total cost of $18,660. The resulting cost savings from reduced disposal and reduced container use was $439,170. Increased costs for waste treatment and disposal of other waste categories and miscellaneous consumables was $84,160. Therefore, the overall cost savings for this activity was $335,140. No quantitative results are currently available for the ORNL segregation project as the project is not complete.

5.3 CLEANUP/STABILIZATION WASTE CASE STUDIES

The major LLW generating categories identified for remediation sites, in order of priority, were remediation activities, decommissioning, and investigation. However, workshop discussions revealed that a prerequisite to implementing any waste minimization in restoration activities was considered good planning. Although good planning is critical to the success of any activity, it is especially important for restoration activities because they are one-time activities and offer only one opportunity for minimizing waste generation. Therefore, prior to discussing case studies for specific waste generating activities, critical planning elements identified at the workshop are described.

5.3.1 Planning Activities

Planning elements identified in the workshop included:

- inclusion of P2 personnel on project teams;
- use of appropriate decision-making tools (such as PPOAs and life cycle analyses);
- incorporation of P2 requirements in contracts and requests for proposals;
- contractor and employee incentives, such as monetary awards;
- regulator negotiations to encourage P2 decisions; and
- project team P2 training.

Many of these tools were used in Fernald's Plant 7 decommissioning project, as described in Section 5.3.2.1. In addition, Fernald has developed a guidance document, *Decision Methodology for Fernald Scrap Metal Disposition Alternatives* (DOE 1996), which provides project teams with a structure for identifying and evaluating alternatives to select the best alternative with respect to specific performance measures. This guidance incorporates a life cycle analysis of each alternative in order to provide a more equal comparison of alternative, allowing for better decision-making.

In addition to the planning elements identified at the workshop, the following steps, specifically, should be considered to minimize and eliminate waste generation.

1. Evaluate new processes/activities to identify waste generation potential prior to approval or start-up of projects. Identify and estimate the cost of waste management before waste generation begins.

2. Evaluate existing waste generating operations for ways to potentially reduce waste generation or identify the possibility of replacement by a new operation or process. Conducting a PPOA is recommended to find and evaluate waste reduction options for existing and new operations.

3. Conduct a life cycle cost analysis to evaluate the true cost/benefit of options for all projects, environmental restoration and decommissioning.

4. Demonstrate that P2 is working by addressing and evaluating the cost/benefit of waste reduction activities and documenting those findings.

These planning elements may also be applied to waste minimization of ongoing processes at operating sites. However, the planning was described here because it is so critical for restoration activities.

5.3.2 Remediation Activities

The recommendations identified for remediation activities were reuse of materials and leaving waste in place. The case studies for these recommendations are presented below.

5.3.2.1 Reuse of materials

Although the following case study is related to an upgrade effort, it is also applicable to similar remediation activities. At LANL, a project was implemented to reuse LLW generated from a soil excavation project.

Contact. Jocelyn Siegel; (505) 845-4623 (see Appendix G).

Baseline. At LANL's Chemistry and Metallurgy Research building, upgrades are being performed to improve the building's stability and electrical systems. These upgrades require soil excavation, and because of the possibility that the soil could contain radioactive contamination, it is considered suspect waste.

LLW Minimization Approach. Soil excavated during the upgrade was used for the construction of a retaining wall, which is part of the building upgrade, rather than being disposed of as LLW.

Results. This LLW minimization activity reduced the amount of LLW to be disposed of by 6400 lb. The one-time cost savings from reduced waste management and disposal cost was $15,481,740.

5.3.2.2 Leave materials in place

A project was implemented at the Inhalation Toxicology Research Institute to reduce LLW generation by excavation control during remediation.

Contact. Jocelyn Siegel; (505) 845-4623 (see Appendix G).

Baseline. This project involved the remediation of 14 acres of earthen lagoons that contained sludge contaminated with ^{137}Cs and ^{90}Sr. Based on preliminary surveys, the total amount of waste that would be generated during excavation was 5500 yd^3.

LLW Minimization Approach. Preliminary wide area surveys were conducted on 100% of all areas (both surface and subsurface) within the lagoon fences, including the floors of the six lagoons and all berm and access areas. Data from these preliminary surveys were plotted and were used as the basis for selecting points for biased measurements. Waste was sorted and segregated in the field based on the initial scanning, and all material was subject to gamma-spectroscopic analysis in the field prior to bagging as waste. This on-the-spot analysis eliminated the problem of suspect waste being categorized as LLW.

Results. This LLW minimization activity avoided the generation of 2000 yd^3 of LLW, with no additional implementation costs. Although additional labor was required for continuous monitoring, an equal amount of labor was not required for waste packaging and handling due to the lower overall waste volume. Based on the per unit costs associated with transportation and disposal of the 3500 yd^3 of LLW generated during the remediation, savings were estimated at $667,500.

5.3.3 Decommissioning Activities

The recommendations identified for decommissioning were recycling/reuse of materials and free release of materials. The case studies for these recommendations are presented below.

5.3.3.1 Recycle/Reuse Materials

At the Fernald site, a project was implemented to reduce LLW disposal from decommissioning activities through recycling of structural steel.

Contact. Bob Lehrter; (513) 648-4966 (see Appendix G).

Baseline. At Fernald, Plant 7 was one of the first decommissioning projects to be undertaken and involved a seven-story contaminated structure that would generate nearly 5700 yd^3 of LLW. The tasks to complete decommissioning of Plant 7 included removal of transite, dismantling, size reduction (cutting up large, bulky items to reduce container void space), segregation, surface decontamination, packaging, certifying, and placing materials into interim storage. Materials designated for disposal were packaged and shipped off-site.

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LLW Minimization Approach. Planned into the project were the recycling of approximately 710 tons of structural steel and the beneficial reuse of 4 tons of lead flashing and lead caps. The structural steel was shipped to an off-site vender to be decontaminated by steel-shot grit blast and/or chemical decontamination and then monitored for unrestricted release.

The coordination of all activities was accomplished through a project team approach. Waste minimization/waste management personnel were involved in all team meetings and briefings in order to effectively coordinate all waste management activities. The functions of the waste minimization personnel were to identify, characterize, and provide volume estimates of the various waste streams; identify waste minimization opportunities; ensure segregation practices were employed; provide and coordinate the delivery of waste containers; remove full waste containers from the project area; place waste into interim storage; store any hazardous waste; and manage LLW for disposal or for recycle/reuse.

The waste minimization coordinator facilitated the characterization of all waste streams anticipated to be generated from the project. Waste stream characterization and volume estimates were compiled and documented to provide the project with a complete synopsis of the types and quantities of wastes to be generated and the disposition options.

The inclusion of waste minimization techniques and procedures in subcontractor agreements and the pre-project training of subcontractors on segregation techniques ensured efficient implementation.

Training was also provided to project and design engineers, as well as all waste management personnel, on incorporating waste minimization principles and practices into remediation projects. The training includes the application of life cycle cost analysis in order to evaluate the cost/benefit of various waste management options.

Results. This LLW minimization activity reduced the amount of LLW by 3458 yd^3 (including structural steel and lead). Because the waste minimization measures were integrated into this project from the planning phase, no estimates of cost savings or implementation cost are available for this activity.

5.3.3.2 Free release of materials

Also at the Fernald site, another project was implemented to reduce LLW disposal from decommissioning activities through recycling of decommissioning waste.

Contact. Bob Lehrter; (513) 648-4966 (see Appendix G).

Baseline. For the Fernald site, five distinct operable units have been defined, each with a corresponding management organization known as a CERCLA/RCRA Unit (CRU). CRU3 is responsible for managing the cleanup of an area that covers 136 acres and consists mainly of the former uranium processing area, including buildings, equipment, stored wastes, and associated materials. Several lots of material, including 120 tons of furnace pots, were targeted for removal from the site.

LLW Minimization Approach. A building at Fernald that was originally designed to decontaminate vehicles and process vessels used in the production of uranium was completed after Fernald's primary mission had changed to ER. This unused facility was, therefore, readily available for use as a decontamination facility. Over a period of two and a half months, the furnace pots (600 pots weighing 400 lb each) were decontaminated primarily through steam/detergent spraying. Some grinding, scraping, and torch cutting were required for small areas of particularly stubborn surface contamination. The pots were then surveyed and cleared for free release after no activity was detected.

Results. This LLW minimization activity eliminated the need to dispose of the structural steel as LLW, reducing the amount of LLW by 240,000 lb. Fernald has a great deal of experience shipping LLW to the NTS for disposal, so an accurate estimate of the cost to disposition the 240,000 lb of furnace pots at NTS, including the material and labor for packaging, transporting, and burying the material, was readily available. The cost to implement the decontamination and free release approach (including on-site processing of the furnace pots, transportation to and from the decontamination building, material handling at the decontamination facility, flame cutting of stubborn contamination spots, decontamination activities, radiological surveying, technical, clerical, supervisory, and management support, and supplies) of approximately $72,500 was about half the estimated cost for disposal at NTS.

5.3.4 Investigation Activities

The recommendations identified for investigation were revision of techniques and revision of decontamination methods. The case studies for these recommendations are presented below.

5.3.4.1 Revision of techniques

Contact. Bob Lehrter; (513) 648-4966 (see Appendix G).

Baseline. Presently, Fernald's groundwater conditions are monitored in 610 wells. Procedures required three or more (depending on the stability of field parameters) well volumes to be purged prior to sampling. During a typical three-month monitoring period at Fernald, 90 to 110 wells are sampled and more than 26,500 L of purge water is generated. Because contaminant concentrations are unknown until laboratory analyses are conducted, all purged groundwater must be handled and treated at considerable expense for treatment and labor.

LLW Minimization Approach. Recent studies suggest that past guidance for removal of three to five well volumes prior to sampling may be unnecessary. Micropurge low-flow sampling has been demonstrated to improve groundwater sampling efficiency, minimize the generation of wastewater, and better ensure the collection of representative groundwater samples from narrow diameter wells with short-screened intervals. At Fernald, two well pairs were selected for micropurge low-flow experiments. Well purging and sampling were accomplished using a dedicated bladder pump to pump at a flow rate approximately equal to an estimated groundwater flow rate. During pumping, field parameters (pH, temperature, dissolved oxygen, and specific conductance) were monitored to determine when stabilization (of conditions) occurred. Each well was sampled four times. Purging was accomplished by either micropurging, purging one well volume, or purging three well volumes, and the sample results were compared. Results showed that micropurging is an acceptable technique for Fernald.

Results. By expanding the use of micropurging where applicable in the Fernald program, it is estimated that the amount of purge water generated at Fernald would be reduced by over 6000 gal/year. The cost savings resulting from reduced labor, rinsate sample requirements, and wastewater treatment and disposal is estimated to be over $52,000/year. The cost to implement the program was minimal since all necessary equipment was already available.

5.3.4.2 Revision of decontamination methods

Contact. Betsy Mitchell; (208) 526-0345 (see Appendix G).

Baseline. Radiological contamination control/work tents were once constructed with wooden framework, plywood doors, lexan windows, stainless steel filter frames, and sleeve clusters. After extensive decontamination, the tents were demolished and disposed of as radioactive waste.

LLW Minimization Approach. Softwall tents are being used extensively at INEL. Softwall tents use exterior tube-lock scaffolding with ropes or ties to support a one-piece sealed PVC unit. In addition, because the PVC is in one sealed piece, it can be easily decontaminated for reuse. The exterior support does not become contaminated and, therefore, does not require decontamination or disposal. The use of softwall suspension tents eliminates the disposal of seven-eighths of the original volume of waste. The tents are constructed with removable floors so that the walls may be used longer even if the floor must be replaced. On average, one tent can be reused as many as 11 times before it must be disposed of. The amount of waste generated with one conventional tent was approximately 420 ft^3. The amount of waste generated (after several uses) with one softwall tent is approximately 40 ft^3.

Results. This LLW minimization activity reduced the amount of LLW by 65,000 ft^3 in 1994 at INEL. The annual cost savings from reduced waste storage and disposal cost for 1993 was approximately $2.4 million. With increasing use of softwall tents throughout INEL, the cost savings is expected to reach $4,000,000/year. The implementation cost of $20,000 involved buying sewing machines and materials to construct the tents.

6. SUMMARY

Tables 6.1 and 6.2 summarize the information in this report for each recommendation for operating sites and restoration sites, respectively. Column three of each table identifies the priority status of each recommendation. Column five shows the number of times each recommendation was reported as an implemented approach in annual reports and other site provided data for the seven studied sites. This offers some indication of the ease of implementation, general applicability, and level of technology development. The last three columns summarize case study results, providing some indication of the waste reduction and economic benefit potential for each recommendation. In addition to these recommendations, note that multiple other approaches are reported in annual reports and recommended in PPOA reports, as summarized in Section 3. These other potential approaches should also be considered when planning LLW minimization activities.

Table 6.1. Recommended LLW approaches for operating facilities

Overall					Case studies		
Generating category	**Waste generation**	**Priority**	**Recommendations**	**Number of approaches**	**Reduction**	**Cost savings**	**Implementation cost**
Suspect waste	Routine and nonroutine	First	Downposting	13	441,180 lb/year	$1,000,000/ year	$79,535
			Controlled entry	5	20,000 lb/year	$94,500/year	$210,000
PPE use	Routine and nonroutine	Second	Segregation	1	Unknown	Unknown	Unknown
			Entry restrictions	8	Unknown	Unknown	Unknown
Effluent treatment	Routine	Third	Change procedures	8	2,600 gal/year (21,892 lb/ year)	$2,600/year	$100,000
			Regenerate GAC	1	140,000 lb	$700,000	None
Miscellaneous	Routine	Fourth	Waste segregation/ volume reduction	13	2,426 ft^3	$335,140	None

GAC = granular activated carbon
LLW = low-level radioactive waste
PPE = personal protective equipment

Table 6.2. Recommended LLW approaches for restoration facilities

Overall					Case studies		
Generating category	**Waste generation**	**Priority**	**Recommendations**	**Number of approaches**	**Reduction**	**Cost savings**	**Implementation cost**
Remediation	Nonroutine	First	Material reuse	2	6,400 lb	$15,481,740	None
			Leave in place	1	2,000 yd^3	$667,500	None
Decommissioning	Nonroutine	Second	Recycle/reuse	6	3,458 yd^3 (1,420,000 lb)	Unknown	None
			Free release	4	240,000 lb	$72,500	None
Investigation	Nonroutine	Third	Revise techniques	5	6,000 gal/year (50,520 lb/ year)	$52,000/year	<$50,000
			Revise decon procedures	0	65,000 ft^3	$2.4 million	$20,000

LLW = low-level radioactive waste

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Appendix A

POINTS OF CONTACT FOR THE LLW MINIMIZATION EFFORT

	DOE contact		Site contact	
	Name	**Phone number**	**Name**	**Phone number**
Operating sites				
INEL	Laura Bingham	(208) 526-7645	John Griffin	(208) 526-6997
			Tom Wheeler	(208) 533-4137
			Betsy Mitchell	(208) 526-0345
LANL	Patty Berglund	(505) 665-5049	Michelle Burns	(505) 665-8291
			Greg Erpenbeck	(505) 665-8289
ORNL	Karen Catlett	(423) 241-2224	Susan Michaud	(423) 576-1562
			Janet Michel	(423) 574-4009
Restoration sites				
Fernald	Pete Yerace	(513) 648-3161	Matt Frost	(513) 648-5685
			Chuck Mench	(513) 648-5662
Hanford	Ellen Dagan	(509) 376-3811	Donna Merry	(509) 376-9773
			Mary Betsch	(509) 372-1627

	DOE contact		Site contact	
Rocky Flats	Regina Sarter	(413) 966-7252	Paul Rablitto	(303) 966-8228
			Susan Anderson	(303) 966-3054
			Rick Turco	(303) 966-2481
SRS	Sherri Johnson	(803) 725-1575	Keith Stone	(803) 557-6317
			John Harley	(803) 557-6332

Table B.1. Potential waste minimization options for PPE waste

PPOA for PPE
Evaluate monitoring results and modify PPE based on results
Create clean work surfaces. Conduct study of techniques to clean work surfaces
Reevaluate PPE selection process and select appropriate PPE for each site
Recycle cardboard from PPE packaging
Assign a "trash cop" at contamination reduction zone
Use remote handling equipment
Develop records to track disposable and launderable PPE uses, purchases, and disposal
Train ER managers in risk analysis and pollution prevention
Evaluate the reuse of respirator cartridges
Limit personnel and time in exclusion zones
Change the contamination zone boundaries as contaminated materials are removed or encapsuled
Provide incentives for project managers to use and identify waste minimization methods
Recycle latex and rubber
Determine cause of inadequate supply of launderable PPE
Use launderable protective clothing
Identify alternatives for yellow gloves
Reevaluate need for skull caps
Reuse PPE that has been scanned and is clean prior to doffing and exiting contamination zone
Evaluate alternative work schedules to maximize time spent in exclusion zone
PPOA for Building Material Decontamination
Adjust work schedules to reduce PPE changes and use launderable PPE
PPOA for the K-25 TSCA Incinerator Operations Level III
Reuse respirators
Radioactive Research Waste Reduction PPOA
Reuse PPE by laundering

ER = environmental restoration
PPE = personal protective equipment
PPOA = pollution prevention opportunity assessment

TSCA = Toxic Substances Control Act

Table B.2. Potential waste minimization options for effluent and related waste

PPOA for the K-25 Site CNF
Identify stormwater infiltration at CNF and reroute sources or cover areas
PPOA for the K-25 TSCA Incinerator Operations Level III
Reduce contaminated wastewater by decontaminating storm drains and process equipment areas
Metals and Ceramics Division Study of Waste Exhaust Filters (ORNL)
Replace HEPA filters with B-2000 filters in some HVAC systems
Implement policy to install HEPA filters by area and not in entire buildings
Re-balance building airflow of areas with dedicated HVAC to reduce exhaust filter waste
Perform environmental and health physics survey of ductwork to determine where B-2000 filters can replace HVAC filters
Enriched Uranium Production Operations at Y-12 Plant
Control rainfall into diked area
Waste Minimization/P2 Study of High-Priority Waste Streams
Substitute HEPA filters with B-2000 filters where applicable
Perform health physics survey of ductwork
Modify processes to include installation of equipment fitted with HEPA filters
Modify processes to incorporate reduced air velocity during back shifts and weekends
Modify processes to incorporate reductions in building airflow

CNF = Central Neutralization Facility
HEPA = high-efficiency particulate arrestor
HVAC = heating, ventilation, and air conditioning
ORNL = Oak Ridge National Laboratory
P2 = pollution prevention
PPOA = pollution prevention opportunity assessment
TSCA = Toxic Substances Control Act

Table B.3. Potential waste minimization options for miscellaneous waste

PPOA of the K-25 TSCA Incinerator Wastewater Stream
Install additional wastewater storage tanks to allow composite sampling, reducing lab waste
PPOA for the K-25 TSCA Incinerator Operations Level III
Substitute metal pallets for wood
Reuse spill response materials
Reuse refractory brick
Substitute metal scaffolding for wood
DOE ORNL Degreasing Solvent Process Waste Assessment
Use ultrasonic cleaning system to replace solvents and degreasers
Reclamation Area of the Assembly Division PWA
Dismantle materials for reuse or easy handling
Increase decontamination of radiological contaminated material
Segregate and launder equipment
Design containers to transport depleted uranium to metal preparation operations
Proof test radiation equipment prior to entry into controlled areas
Revise policy to permit point of generation storage and in situ decay of short lived isotopes
Extend radioactive production cycles to minimize waste generated in start/stop production activities
Arrange reuse of containers with vendors
Perform quarterly division inspections
Reduce research and operations with radioactive materials and processes
Substitute nonabsorbant floor coverings for blotter paper
Provide guidance to health physics for implementation of uniform green tagging procedures

DOE = U.S. Department of Energy
ORNL = Oak Ridge National Laboratory
PPOA = pollution prevention opportunity assessment
PWA = process waste assessment
TSCA = Toxic Substances Control Act

Table B.4. Potential waste minimization options for decommissioning waste

PPOA for Building Material Decontamination
Treat in place or stabilize discovered process waste for transport
Use plastic sheets/tarps to contain decommissioning debris and decontamination materials
Implement surface cleaning and removal of floors, walls, and other structural features
Segregate waste streams, contain to prevent cross-contamination, and use appropriate containers
Use containment to prevent cross-contamination
Implement new and emerging removal technology
Use correct commercial absorbants
Segregate building material waste streams for decontamination and recycling at DOE sites or for commercial release
Implement site decontamination, dismantling and removal of surface structures and equipment, and entombment of foundation and debris
Y-12 Waste Management Division Process Waste Assessment Report
Minimize frequency, quantity, and number of waste samples taken

DOE = U.S. Department of Energy
PPOA = pollution prevention opportunity assessment

Table B.5. Potential waste minimization options for investigation waste

PPOA for Geological subsurface Investigations (Oak Ridge Reservation)
Use dedicated equipment to reduce decontamination
Refill boreholes with soil cuttings using compaction method
Spread soil cuttings on ground in contaminated areas if no epidermal risk exists
Use thin wall, small diameter drill
Use direct push sampling methods
Use recyclable equipment to reduce decontamination
Use disposable equipment to reduce decontamination
Reduce solvent rinse use during decontamination
Use nonintrusive methods to site wells
Use vacuum pump sampling to reduce decontamination needs
Use lab and field analysis to determine need for decontamination before equipment is reused
Increase mechanical cleaning to reduce water
Sample wells immediately after development, using development as first purge
Filter and reuse decontamination water
Use a mobile, reusable decontamination vessel
Reuse plastic sheeting to maximum extent
Place soil cuttings in excavation of contaminated area and cover with clean soil
Pour purge/development water on ground in contamination area
Pour purge water back into well casing
Micro purge wells until parameters are stable
Store soil in contaminated area for use in remedial activities
Enriched Uranium Production Operations at Y-12 Plant
Improve material segregation in production areas
Improve characterization of solid waste
Y-12 Waste Management Division Process Waste Assessment Report
Add canopy over diked area to reduce rainwater collection
Send empty vermiculite bags to sanitary landfill
Radioactive Research Waste Reduction PPOA

PPOA for Geological subsurface Investigations (Oak Ridge Reservation)
Restrict material introduction into controlled areas to precise sample or component sizes

PPOA = pollution prevention opportunity assessment

Appendix C

RADIOLOGICAL CONSIDERATIONS IN WASTE MINIMIZATION

Regulations in 10 CFR 835 ("Occupational Radiation Protection") require posting of radiologically-contaminated areas for controlling the spread of radiological contamination and for protecting workers against the contamination. Contamination is defined in 10 CFR 835 Appendix D and in Table 2-2 of the *DOE Radiological Control Manual*. Appendix D to 10 CFR 835 has been modified in Table C.1 of this report to reflect the values for tritium compounds given in the *DOE Radiological Control Manual*. The values in Table C.1 provide the basis for legally defining contamination areas.

Table C.2 presents the surface contamination levels that cannot be exceeded if any material is to be released from a controlled area to any location whose unrestricted access is allowed. These values were obtained from Figure IV-1 of DOE Order 5400.5. They have been modified to include guidance for transuranics obtained from other DOE sources.

A few definitions consistent with 10 CFR 835 and the *DOE Radiological Control Manual* will help clarify radiological requirements.

- *Controlled area* is any area to which access is managed in order to protect individuals from exposure to radiation and/or radioactive materials.
- *Contamination area* is any area where contamination levels are greater than the values shown in Table C.1, but less than or equal to 100 times those levels.
- *High contamination area* is any area with contamination levels greater than 100 times the values given in Table C.1.
- *Airborne radioactivity area* is any area where the measured concentration of airborne radioactivity, in excess of natural background, exceeds or is likely to exceed 10% of the derived air concentration values in Appendix A or Appendix C of 10 CFR 835.
- *Radiation area* is any area accessible to individuals in which radiation levels could result in an individual receiving a deep dose equivalent in excess of 5 mrem in 1 hour at 30 cm from the source or from any surface that the radiation penetrates. *High radiation area* is one with a possible deep dose equivalent of 100 mrem/hour at 30 cm. *Very high radiation area* is one with a possible absorbed dose in excess of 500 rad in 1 hour at 1 m from any surface.
- *Radiological area* is any area within a controlled area that must be *posted* as a "radiation area," "high radiation area," "very high radiation area," "contamination area," "high contamination area," or "airborne radioactivity area" in accordance with 10 CFR 835.603.

- *Radiological buffer areas* are areas established within a controlled area to provide secondary boundaries to minimize the spread of contamination and to limit deep dose equivalents to general employees to less than 100 mrem/year.

- *RMMA* is an area in which a reasonable potential exists for items becoming contaminated due to the presence of unencapsulated or unconfined radioactive material or exposure to beams of particles (e.g., neutrons) capable of causing activation in the item.
- *Radiological work permit* is a document used to establish control of radiation exposures associated with intended work in a radiological area; it informs workers of area radiological conditions and entry requirements.

Table C.1. Surface radioactivity values used to define contaminated areas[a]
[in disintegration per minute (dpm)/100 cm[b]]

Radionuclide	Removable[b,c]	Total (fixed + removable)[b,d]
U-natural, ^{235}U, ^{238}U, and associated decay products	1,000	5,000
Transuranics, ^{226}Ra, ^{228}Ra, ^{230}Th, ^{228}Th, ^{231}Pa, ^{227}Ac, ^{125}I, ^{129}I	20	500
Th-natural, ^{232}Th, ^{90}Sr, ^{223}Ra, ^{224}Ra, ^{232}U, ^{126}I, ^{131}I, ^{133}I	200	1,000
Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except ^{90}Sr and others noted above[e]	1,000	5,000
Tritium organic compounds; surfaces contaminated by HT, HTO, and metal tritide aerosols[f]	10,000	10,000

[a] The values in this table apply to radioactive contamination deposited on, but not incorporated into the interior of, the contaminated item. Where surface contamination by both alpha- and beta-gamma-emitting radionuclides exists, the limits established for alpha- and beta-gamma-emitting radionuclides should apply independently.

[b] As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

[c] The amount of removable radioactive material per 100 cm^2 of surface area should be determined by swiping the area with dry filter or soft absorbent paper, applying moderate pressure, and then assessing the amount of radioactive material on the swipe with an appropriate instrument of known efficiency. (Note: The use of dry material may not be appropriate for tritium.) When removable contamination on objects of surface area less than 100 cm^2 is determined, the activity should be based on the actual area and the entire surface should be wiped. Except for transuranics and ^{228}Ra, ^{227}Ac, ^{228}Th, ^{230}Th, ^{231}Pa, and alpha emitters, it is not necessary to use swiping techniques to measure removable contamination levels if direct scan surveys indicate that the total residual surface contamination levels are within the limits for removable contamination.

[d] The levels may be averaged over one square meter provided the maximum surface activity in any area of 100 cm^2 is less than three times the value specified. For purposes of averaging, any square meter of surface shall be considered to be above the activity guide G if (1) from measurements of a representative number n of sections it is determined that $1/n \; \Sigma_n \; S_i \geq G$, where S_i is the dpm/100 cm^2 determined from measurement of section i or (2) it is determined that the sum of activity of all isolated spots or swipes in any 100 cm^2 area exceeds 3G.

[e] This category of radionuclides includes mixed fission products, including ^{90}Sr, which is present in them. It does not apply to ^{90}Sr, which has been separated from other fission products or mixtures where the ^{90}Sr, has been enriched.

[f] The values in this table are consistent with those given in Appendix D to 10 CFR 835 and Table 2-2 of the DOE Radiological Control Manual, except for the limits for tritium compounds. The values stated here are taken from the *Radiological Control Manual*. Appendix D to 10 CFR 835 states that these values are "RESERVED."

Table C.2. Surface contamination guidelines for unrestricted release to the public

	Allowable total residual surface contamination[a] (dpm/100 cm^2)		
	Average[c,d]	**Maximum[d,e]**	**Removable[d,f]**
Transuranics[g], ^{226}Ra, ^{228}Ra, ^{230}Th, ^{228}Th, ^{231}Pa, ^{227}Ac, ^{125}I, ^{129}I	100	300	20
Th-natural, ^{232}Th, ^{90}Sr, ^{223}Ra, ^{224}Ra, ^{232}U, ^{126}I, ^{131}I, ^{133}I	1,000	3,000	200
U-natural, ^{235}U, ^{238}U, and associated decay products, alpha emitters	5,000	15,000	1,000
Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except ^{90}Sr and others noted above[h]	5,000	15,000	1,000

[a] As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.
[b] Where surface contamination by both alpha- and beta-gamma-emitting radionuclides exists, the limits established for alpha- and beta-gamma-emitting radionuclides should apply independently.
[c] Measurements of average contamination should not be averaged over an area of more than 1 m^2. For objects of less surface area, the average should be derived for each such object.
[d] The average and maximum surface dose rates associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h and 1.0 mrad/h, respectively, at 1 cm.
[e] The maximum contamination level applies to an area of not more than 100 cm^2.
[f] The amount of removable radioactive material per 100 cm^2 of surface area should be determined by wiping the area of that size with dry filter or soft absorbent paper, applying moderate pressure, and then assessing the amount of radioactive material on the wiping with an appropriate instrument of known efficiency. When removable contamination on objects of surface area less than 100 cm^2 is determined, the activity per unit area should be based on the actual area and the entire surface should be wiped. It is not necessary to use wiping techniques to measure removable contamination levels if direct scan surveys indicate that the total residual surface contamination levels are within the limits for removable contamination.
[g] In DOE Order 5400.5, these values are listed as "RESERVED." No DOE Order or federal regulation provides guidance for unrestricted release of these radionuclides to the public. The numbers presented in this table are based on NRC *Regulatory Guide 1.86*. These numbers are referenced in the May 15, 1984, memorandum of J. R. Maher, "Unrestricted Release of Radioactively Contaminated Personal Property," and the May 26, 1995, memorandum of H. W. Hibbits," Unrestricted Release Limits for Transuranic Contaminated Equipment and Property."
[h] This category of radionuclides includes mixed fission products, including ^{90}Sr which is present in them. It does not apply to ^{90}Sr which has been separated from other fission products or mixtures where the ^{90}Sr has been enriched.

There are two notable differences between Table C.1 and Table C.2. First, the total contamination limit for the "Transuranics, et. al."

is five times higher in Table C.1, although the removable contamination values are the same in each table. Second, Table C.2 has no comparable entry for tritium compounds as does Table C.1. Hence, since tritium is a beta emitter, the values for beta emitters in Table C.2 must be used for tritium compounds. In addition, footnote d of Table C.2 provides a surface dose rate not to be exceeded for beta-gamma emitters. For some mixtures of radionuclides, this may simplify surface radioactivity measurements.

Appendix D is available by request

Appendix E

TASK TEAM WORKSHOP ATTENDEES

Name	Office	Phone Number
Lisa Allmon	IT Cincinnati	(513) 782-4686
Russell Goff	Radian Oak Ridge Office	(423) 220-8186
Bill Goldsmith	Radian Oak Ridge Office	(423) 220-8196
Chris Ischay	Lockheed Idaho	(208) 506-4382
Pete J. Yerace	DOE Fernald	(513) 648-3161
Sherri Johnson	DOE Savannah River	(803) 725-5793
Bob Lehrter	Fernald/FERMCO	(513) 648-4966
Greg McBrien	DOE EM-77	(301) 903-1385
Janet Michel	LMES P2	(423) 574-4009
Kimberly Murray	Radian Oak Ridge Office	(423) 220-8202
Catherine Schidel	DOE-ORO	(423) 241-6314
Jocelyn Siegel	DOE Albuquerque	(505) 845-4623
Sam Suffern	LMES Waste Management	(423) 576-0126
Frank Sweeney	LMES ESWMO	(423) 574-9591
Ron Vogel	Radian Oak Ridge Office	(423) 220-8136

Tom Youngblood	DOE-ORO	(423) 576-2867

Appendix F

WORKSHOP MATERIALS

The material contained in this appendix was distributed to workshop attendees. For each generating category an evaluation table was prepared to record the scores of the evaluation criteria.

Suspect waste

Approaches	Economics	Reduction	Generation Rate	Technical Risk	EPA Hierarchy	Compliance	Potential	Total Score	Comments
HEPA Air Filter									
Equipment Modification									
Change Procedures									
Redirect Runoff									
Reuse liquid LLW									
Regenerate Carbon									
Segregate/ Bypass Clean Water									

HEPA = high-efficiency particulate air
LLW = low-level waste

Attachment 1

DOE-Wide LLW Minimization Evaluation and Strategy Workshop
Discussion Group Assignments

Suspect and miscellaneous	PPE and effluent treatment	Site investigation and decommissioning
Greg McBrien	Mathew Zenkowich	Robert Fleming
Jocelyn Siegel	Andrew Szilagyi	Pete Yerace
Frank Sweeney	Sherri Johnson	Mary Betsch
Janet Michel	Tom Youngblood	Matt Frost
Bill Goldsmith	Russell Goff	Kimberly Murray
Jan Strous	Sam Suffern	Ron Vogel

Attachment 2

Evaluation Criteria

Decision Matrix

	Score
Low	1
Medium	2
High	3

Criteria Definition

1. Economic Feasibility—The cost of implementing the option verses the cost savings resulting from that implementation.

   a. Low—Cost of implementation is significantly greater than the savings derived from implementation.
   b. Medium—Cost of implementation is roughly equal to savings.
   c. High—Cost of implementation is much less than the savings derived from option implementation.

2. Quantity of Reduction—The amount of reduction in either volume or weight of the waste stream with option implementation.

   a. Low—A small volume or weight reduction (0-25%).
   b. Medium—A significant volume or weight reduction (26-50%).
   c. High—A major volume or weight reduction (51-100%).

3. Quantity of Generation—The size of the waste stream at a site versus the overall LLW stream quantity.

   a. Low—Less than 10% of the total LLW.
   b. Medium—11-40% of the total LLW.
   c. High—41-100% of the total LLW.

4. Technical Risk—The likelihood that an option when implemented will perform as projected.

   a. Low—Risk is great that the option will not work as projected.
   b. Medium—The option will probably work to reduce waste generation to some degree.
   c. High—The option will work totally as provided or exceed expectations.

5. EPA Hierarchy—How the option meets the EPA hierarchy of source reduction, reuse/recycle, treatment, and disposal.

   a. Low—Disposal and treatment.
   b. Medium—Reuse/Recycling.
   c. High—Source reduction.

6. Compliance—The options ability to meet federal, state, and local laws and regulations and also comply with DOE orders and regulations.

    a. Low—Does not comply with local, state, or federal laws and regulations.
    b. Medium—Complies with laws and regulations but must have a DOE order change in order to implement.
    c. High—Complies with all laws, regulations, and DOE orders.

Attachment 3

DOE-Wide LLW Minimization Evaluation and Strategy Workshop

March 5, 1996
Oak Ridge, Tennessee

Draft Agenda

8:15	Registration
8:30	Introduction, Meeting Purpose, and Overview
8:45	Review of Waste Categories (see report) and Evaluation Criteria (provided in this packet)
9:30	**Breakout Session 1** - During this first breakout session, teams will prioritize potential options using identified criteria
11:30	Working Lunch
12:15	**Breakout Session 2** - The goal of this session will be for each team to screen, analyze, and rank options identified as "high priority" in Breakout Session 1
2:15	Break
2:30	Reconvene - Teams will present results of Sessions 1 and 2
4:15	Break
4:30	Discussion of Results, Summary, and Recommendations
5:00	Adjourn

Appendix G

CASE STUDY CONTACTS

Type of facility	Generating category (in order of importance)	P2 recommendation	Case study source	Site/Program affiliation	Phone number	Fax number	E-mail address
Operating	Suspect waste generation	Downposting	Sheila Poligone	ORR	(423) 241-2568	(423) 241-2857	SS9@ORNL.GOV
		Controlled entry	Sheila Poligone	ORR	(423) 241-2568	(423) 241-2857	SS9@ORNL.GOV
	PPE use	Segregation	Jason Darby	FUSRAP	(423) 241-6343	(423) 576-0956	DARBYJ@ORO.DOE.GOV
		Entry restrictions	Jocelyn Siegel	Albuquerque	(505) 845-4623	(505) 845-6286	JSIEGEL@DOEAL.GOV
	Effluent treatment	Change procedures	Susan Michaud	ORNL	(423) 576-1562	(423) 241-2843	SUN@ORNL.GOV
		Regenerate carbon	Susan Anderson	Rocky Flats	(303) 966-3054	(303) 966-3407	Not available
	Miscellaneous	Waste segregation	Tom Wheeler	INEL	(208) 533-4137	(208) 533-4901	Not available
Restoration	Remediation	Reuse materials	Jocelyn Siegel	Albuquerque	(505) 845-4623	(505) 845-6286	JSIEGEL@DOEAL.GOV
		Leave in place	Jocelyn Siegel	Albuquerque	(505) 845-4623	(505) 845-6286	JSIEGEL@DOEAL.GOV
	Decommissioning	Recycle/reuse	Bob Lehrter	Fernald	(513) 648-4966	(513) 648-5701	Not available
		Free release	Bob Lehrter	Fernald	(513) 648-4966	(513) 648-5701	Not available
	Investigation	Revise techniques	Bob Lehrter	Fernald	(513) 648-4966	(513) 648-5701	Not available
		Revise decontamination methods	Betsy Mitchell	INEL	(208) 526-0345	(208) 526-4775	Not available

FUSRAP = Formerly Utilized Sites Remedial Action Program
INEL = Idaho National Engineering Laboratory
ORNL = Oak Ridge National Laboratory
ORR = Oak Ridge Reservation
P2 = pollution prevention
PPE = personal protective equipment